CHILLED WATER STUDY (PHASE 1)

VA Medical Center, Phoenix, AZ

Executive Summary

The chilled water system at the VA Phoenix Campus is modeled using software. The software model is adjusted until accuracy is within 10% of measured. Existing buildings and future buildings are included in the model. The purpose of the software model is to 1) identify existing deficiencies, 2) assess the impact of future buildings, and 3) propose modifications to aid future buildings and improve energy efficiency. Construction Documents accompany this study that draft the proposed modifications.

The study identifies several deficiencies that require immediate attention. Correcting the deficiencies increases comfort and reduces energy consumption.

1. Undersized Piping
2. Undersized Cooling Coils
3. Missing or Misbalanced Valves
4. Pipe Blockages

The study proposes several new modifications. The modifications re-route the chilled water such that 1) pumping energy is reduced and 2) future buildings may connect to the existing chilled water piping.

1. New Piping Main to Penthouse
2. New East Branch Piping
3. New West Branch Piping
4. New Chillers
5. New Pumps

The existing Central Plant systems are analyzed. Control of the pumps and chillers is discussed. The study recommends that pumps no longer be controlled by ‘delta-T’. Recommendations are made regarding future energy improvements and control schemes.

The existing Chilled Water Storage system is analyzed. The existing storage system is shown to provide only 5.5 hours of use in July. The impact of future buildings and benefits of cooling coil improvements are calculated.

The study provides a reference Project Schedule with Phases and Milestones. The schedule organizes the aforementioned deficiencies and modifications into distinct Milestones. The future buildings and future air handling units make up each Phase. The milestones are strategically ordered to provide a 20% safety factor with chiller and pump capacities throughout each phase.

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CHILLED WATER STUDY

VA Medical Center, Phoenix, AZ

1. Introduction

This study models and analyzes the chilled water system at the VA Campus in Phoenix, AZ. The impact of future buildings is discussed. Deficiencies are identified and recommendations are made. Construction Documents that draft the necessary modifications accompany this report.

The existing chilled water distribution covers the entire VA campus and consists of several interconnected loops. Many of the existing air handling units are failing, and the distribution continues to be problematic and misunderstood. The list of future buildings was provided by the VA, and included:

- Rehabilitation/Prosthetic
- Emergency Room
- CLC Expansion
- Mental Health 1
- Mental Health 2
- Dental Clinic
- Surgery

1.1. Project Scope

The following scoping paragraphs were provided by the VA. The purpose of this Chilled Water Study is to fulfill the following requirements.

A. *The A/E shall provide a complete chilled water study for existing and proposed systems. At a minimum, this study will show.*

   i. *At what operating pressure and differential pressure the central plant must operate to satisfy all demands on campus. This portion of the study will assume the currently proposed 12" interconnection is installed. Additionally, this portion of the study will list, in order of the highest constraint to the lowest constraint, where in the system the constraints are that prevent the plant from operating at a10PSI differential, and what changes must be made to the system to eliminate each of the constraints.*

   ii. *What changes must occur to the existing system in order to allow the plant to run with a 10PSI pressure differential and satisfy all of the loads, both existing and planned.. These studies are to include a 20% factor of safety.*

   iii. *The effect new /additional buildings will have on the existing chilled water storage tank, and at what point the tank must be expanded.*

   iv. *The capacity of the existing plant and what changes are required to maintain the required redundancy and capacity to support the campus.*

B. *Provide for design of recommended changes required to accommodate any new or planned construction to include the completion of a chilled water loop if required.*

C. *Identify parasitic and stand alone systems and provide chilled water piping for future replacement of equipment.*

D. *Identify any inefficient or poorly installed systems, included any areas which could be improved upon through a more efficient installation. Incorporate valves, etc. as required to improve maintainability of the system if identified as necessary.*

1.2. Terminology

Throughout this study and previous conversations with the VA, terms are freely used that may need some background information to those not familiar with the VA campus.

Definitions and Abbreviations

- Measured: Physical pressure, temperature, and flow measurements were gathered at the VA. The physical measurements are used to validate the *model* values.
- Model: The values referred to as *modeled* are generated by the software program (Pipe-Flo).
- Monsoon: Maximum cooling load in Phoenix does not occur during the hot/dry conditions. Instead, max load occurs when moderately hot yet humid conditions (July, August).
- AH or AHU: Air Handling Unit
- BAS: Building Automation System
- CH: Central Plant Chillers. CH-1 is newer Trane, CH-2 is older McQuay, and CH-3,4 are York.
- CHW, CHS, CHR: Chilled water, supply, and return
- CHWP: Primary chilled water pumps
- Cv-Value: Describes the pressure drop of control valves
- FPS: Feet per second
- GPM: Gallons per minute
- PSI: Pounds per square inch (gage)
- O/A: Outside air
- S/A: Supply air
- SCHWP: Secondary chilled water pumps ("House Pumps")
- TAB: Test-and-Balance Contractor

Locations

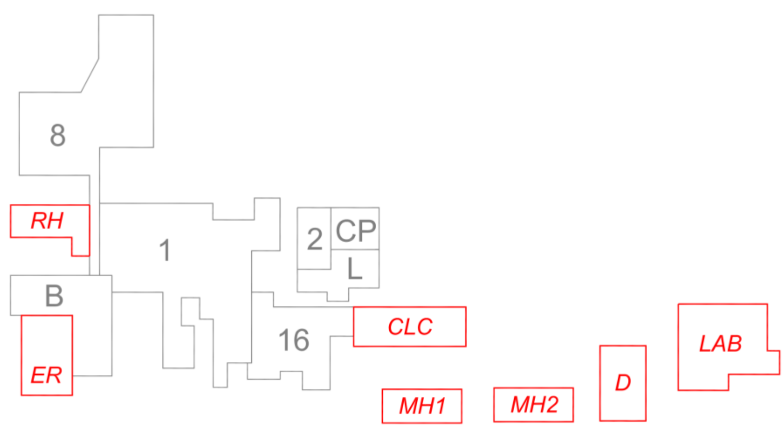

Figure 1. VA Campus site plan, future building in red.

Names and locations are often abbreviated.

- Building Abbreviations (Figure 1): *Existing Buildings*: 1 = Old Hospital (Bldg 1), 2 = Facilities (Bldg 2), 8 = Ambulatory Care (ACC, Bldg 8), 16 = Nursing Home (CLC, Bldg 16), B = Bed Tower, CP = Central Plant, L = Laundry. *Future Buildings*: CLC = CLC Expansion, D = Dental, ER = Emergency Clinic, LAB = Existing Research Lab (Bldg 21, new chilled water), MH1 = Mental Health (First), MH2 = Mental Health (Second), RH = Rehabilitation.
- 8" Main (*Bldg 1 Original*): The original VA campus designed in 1949 had only an 8" chilled water main from the Central Plant. This main still serves much of Building 1 except for the main Bed Tower.
- 12" Main (Bed Tower): The 8-story Bed Tower was designed in 1976, and was served by 12" chilled water mains from the Central Plant.
- ACC 8" Main: The Ambulatory Care Center (Building 8) was designed in 1996, and was served by 8" chilled water mains from the Central Plant (in addition to the original 8" mains from 1949).

- 6” Tie-in (*or 6” Bypass*): The existing 8” Main from 1949 was *tied-in* with the existing 12” Main from 1976. This work was done in September of 2010. The 6” CHW piping that connects the two mains is also commonly referred to as *“bypass”* piping.
- 4” Tie-in (*or 4” Bypass*): The existing 5” Branch to AH-12 from 1949 was *tied-in* with the existing 12” Main from 1976. This work was done in early 2011.
- Plant: Central Plant within Building 2.

2. Software Model

The chilled water distribution and Central Plant were modeled with software. Experiments were done and data recorded to correct the model. The model will then be used to predict future behavior of the plant and distribution when the campus is expanded.

2.1. Pipe-Flo Modeling Software

The only way to model a large campus such as VA is with software capable “network analysis” using the Darcy-Weisbach method. Alternative methods used by Engineers, such as Excel spreadsheets using the Hazen-Williams method, will simply not achieve accurate results. *Network Analysis* is required when the piping contains several interconnected branches, such as the recent 6” tie-in piping. Using only spreadsheets becomes problematic as finding the solution requires several iterations and initial guesses at pressures and flows.

The modeling software package “Pipe-Flo” by ESI was chosen to model the VA campus (Figure 2). More information can be found on ESI’s website, but for our purposes the VA Campus required the following features:

- Network Analysis using Darcy-Weisbach
- Pump curves (with minimum NPSH and motor RPM adjustment)
- Automatic flow control valves (for AHUs)
- Piping elevations (for accurate comparison with measured PSIG)
- Fittings database (elbows, tees, valves, etc with known loss curves)
- Piping database (for different levels of friction with the 1949, 1976, and recent piping)
- Capable of modeling compressible fluids, such as steam

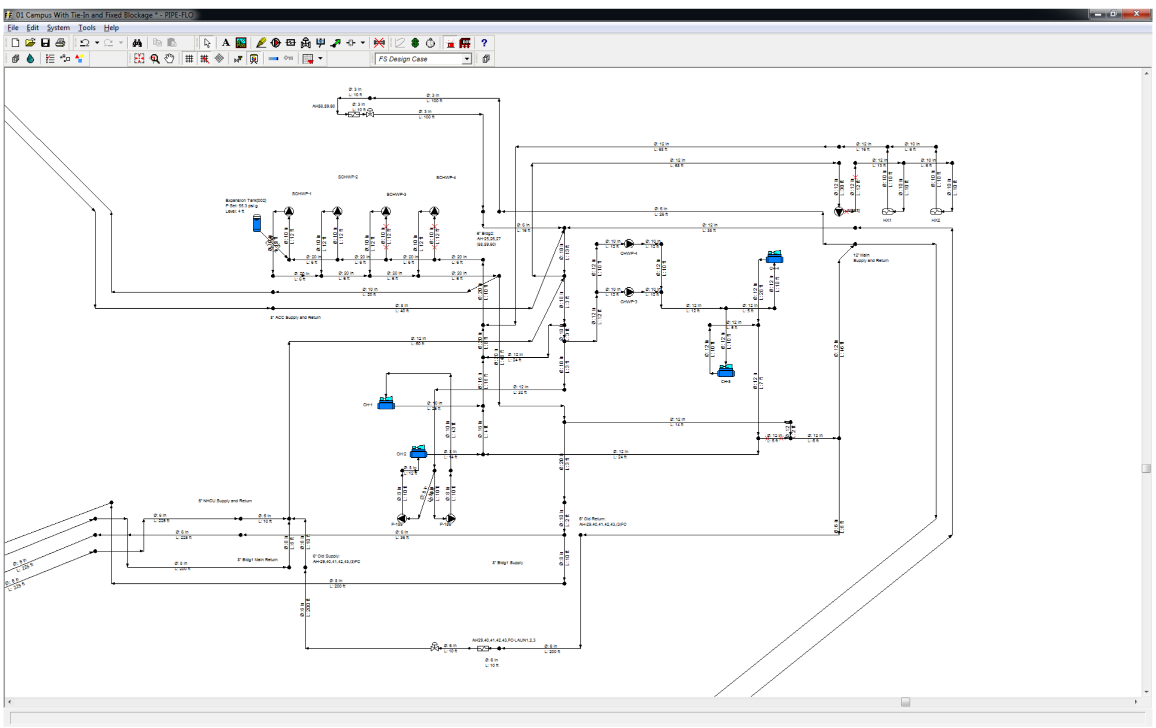

Figure 2. Chosen modeling software for VA Campus (Pipe-Flo by ESI).

2.2. Preliminary Model Creation

Many of the initial pipe length and fitting take-offs were done with the aid of a recently completed project. That project created a 3D model of the chilled water system across the entire VA Campus (Figure 3).

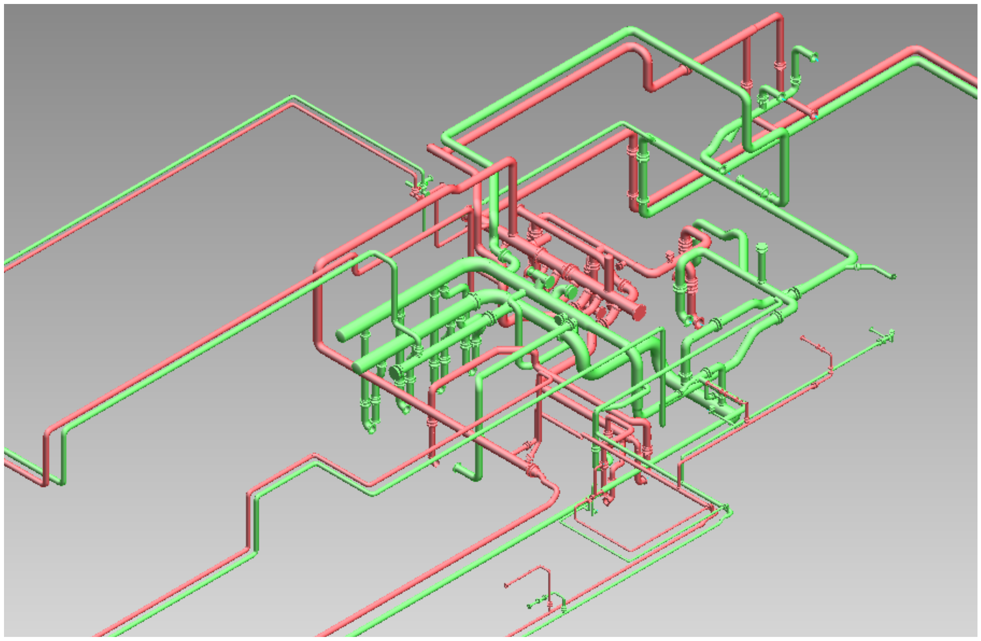

Figure 3. 3D Model of chilled water across entire VA campus.

Other hydronic information was *preliminarily* gathered as follows.

- Pump model, horsepower, and speed were recorded on site and from a recent CXC report.
- Chiller and Heat Exchanger model numbers were recorded. The manufacturers were contacted and provide the pressure drop information.
- Several of the AHU coil data was from original submittals, as most were replaced recently. Older AHU coil data was obtained from original as-built documents, though not as accurate.
- Where possible, Control Valve data was from original submittals. Older valve data was assumed using flow rate and a 5 PSI drop.
- Balancing Valves were initially ignored.

As will be discussed further in Section 3, this preliminary model was then verified against actual measurements. Where the model was significantly different, the cause was investigated and corrected. The relevant coil data, control valve data, and balancing valve data has since been identified, and the *software model now agrees with actual measurements to within 10% accuracy or better*.

2.3. Data Input and Excel Macros

The PipeFlo model by itself is rather *static* as it only contains the hydronic information. For example, changing the Outside Air Temperature changes all coil GPMs—which then would require individual updates of all valve GPMs in PipeFlo—which then would be a long and frustrating task. Instead, PipeFlo allows the model to be controlled by Excel macros.

INPUT PARAMETERS		
OADB	95	*Outside Air Temperature, °F*
OAHR	0.0150	*Outside Air Humidity Ratio, lbw/lba*
PHASE	0	*Phase Number for Schedule. Auto Enables Milestones.*
MODE0	0	*Tower Heat Exchanger Mode (1=Exchange, 0=Disabled)*
MODE1	3	*Lab Chiller Booster Mode (1=Plant, 2=Iso, 3=Boost)*
MODE2	3	*Surgury Chiller Booster Mode (1=Plant, 2=Iso, 3=Boost)*
MODE3	0	*Water Storage Mode (1=Exchange 0=Disabled)*
XLINK1	1	*8" and 12" Loop Connection (1=Connected, 0=Disconnected)*
XLINK2	1	*4" and 12" Loop at AH-12B (1=Connected, 0=Disconnected)*
QUIRK1	1	*PipeFlo Quirk with Valves (1=Invalid to 100%, 0=All to Automatic)*
QUIRK2	0	*PipeFlo Quirk with House Pumps (1=Fixed Speed, 0=All to Automatic)*

Update Spreadsheet!

Correct Pipe-Flo!

Figure 4. Master Parameter Matrix that automatically updates PipeFlo by macros.

A spreadsheet was created that summarized all relevant information into 11 simple parameters (Figure 4). Changing any of these parameters cascades to all AHUs and recalculates the software model.

The spreadsheet and software model include the following characteristics that aided accuracy and productivity.

- Phase. Instead of creating multiple PipeFlo models and spreadsheets, the one model and one spreadsheet include the existing AHUs and all future AHUs, pumps, and piping. The future items are dynamically enabled and disabled by the PHASE parameter.
- Cooling Loads. After calculating the Outside Air Enthalpy and Mixed Air Enthalpy (corrected for Energy Recovery), the waterside GPM is determined. The GPM is linearly dependent upon the coil delta-T, which was determined from VA submittals or measured.
- Sensible Heat Ratio. Using the Outside Air Temperature (OADB) and the averaged Sensible Heat Ratio, the Return Air Temperature is calculated for each AHU (Figure 5). The actual Return and Supply Air Temperatures were recorded at the VA to setup the baseline numbers.
- Controls: Through PipeFlo the control valves automatically adjust. However, the spreadsheet monitors the control valves for 'Invalid', 'Choked', or 'Range' status (red status in Figure 5). If needed, the excel sheet will then override the valve in the PipeFlo model to be 100% open. Nearly all relevant Cv-values were recorded during field visits.
- Secondary Pumps. Though the actual VA pumps control to pressure and temperature, the spreadsheet has the advantage of knowing the desired GPM. The Pump Decision Matrix (Figure 7) automatically enables the correct number of pumps in PipeFlo and adjusts RPMs.
- Verification. The Building Automation System (BAS) at the VA has a summary screen that lists flows, temperatures, and pressures. The spreadsheet was updated to resemble the BAS screen such that experimental results could be quickly verified (Figure 6).

AIR HANDLING UNIT SCHEDULE													CONTROL VALVE				
AHU MARK	HISTORIC MARK	LOOP	ENRGY RECOV	SA CFM	OA CFM	RA°F	SA°F	MBH	DESIGN dT °F	GPM	ID	PIPEFLO	Cv VALUE	STATUS	IV->100%	ALL AUTO	ACTUAL GPM
AH-C	SINCE 1971	B	0%	133000	26600	77.5	60	3457	10	**691**	~N{266}	102	370	-	-	-	385
AH-D	SINCE 1971	B	0%	133000	26600	77.5	60	3457	10	**691**	~N{268}	691.39104934662	370	Invalid	0		691
AH-1	OR-AH-1	B	65%	10850	2190	71.1	51	271	9	**60**	~N{417}	60.2325024845477	41	Range	0		60
AH-1.1	OR-AH-2	B	65%	7300	1760	71.0	53	171	14	**24**	~N{442}	23.7096658701746	25	60% open			24
AH-2	SINCE 198? (AH8, 1971)	B	27%	7360	7360	74.4	53	449	10	**90**	~N{127}	89.7712991075057	47	Invalid	0		90
AH-3	SINCE 1971	B	0%	4500	0	82.0	53	135	10	**27**	~N{130}	26.9352	14	Invalid	0		27
AH-4	SINCE 198? (AH11, 1976; S-21 1949)	B	0%	1200	300	77.7	58	37	10	**7**	~N{129}	7.4176575723648	3	Invalid	0		3
AH-4A	(AH12, 1976; S-19, 1949)	1	0%	1300	1300	78.0	53	98	10	**20**	~N{159}	19.594411735808	8	Invalid	0		8
AH-5	SINCE 198? (AH7, 1976; S-4, 1949)	1	0%	13400	2000	78.0	53	445	19	**47**	~N{453}	46.8697611510514	21	Invalid	0		47
AH-6	SINCE 1971	B	0%	4000	600	78.0	53	133	10	**27**	~N{122}	26.6124177203753	25	Invalid	0		27
AH-7A	SINCE 1981 (AH12, 1977; S-12, 1949)	1	0%	14000	6600	78.0	53	689	19	**72**	~N{633}	72.4828375463865	31	Choked			72
AH-8	SINCE 1976 (S-5, 1949)	1	46%	4600	4600	75.6	53	237	12	**39**	~N{171}	39.4267599424783	38	Invalid	0		39
AH-8A	SINCE 1995 (NEW)	1	0%	2080	2080	77.7	58	130	10	**26**	~N{170}	26.0996814793728	13	Invalid	0		26
AH-9	SINCE 1976 (S-7, S-20, 1949)	1	0%	9000	1350	76.8	53	290	19	**30**	~N{173}	30.4907747834	14	Invalid	0		30
AH-10	SINCE 199? (AHU6, 1976; S14, S15, 1949)	1	0%	13900	2350	73.2	55	382	12	**65**	~N{394}	65.2416316835563	45	Invalid	0		65
AH-11	SINCE 1996 (AH2, 1976; S-18 1949)	1	0%	10100	1500	76.8	53	324	19	**34**	~N{397}	34.1372174520203	16	Invalid	0		34
[illegible]	SINCE 1996 (AH1, [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

Figure 5. Air Handling Unit Matrix (red Indicates that GPM differs from desired)

AVERAGE CHWR TEMPS		
LOOP	GPM	dT °F
B	1707	10.1
L	308	17.6
1	785	17.5
8	1219	10.0
16	238	20.0
2	134	10.0
TOTAL	4392	12.5

DELTA-P			
ID	ID	PSID	AREA
~N{388}	~N{325}	26.95	PLANT
~N{131}	~N{120}	11.12	TOWER
~N{198}	~N{191}	22.1	BLDG8
~N{225}	~N{168}	12.2	BLDG1

FLOW STATIONS			
MARK	DESCRIPTION	ID	GPM
CW1	BLDG 2	~P{549}	181.4
CW3	BLDG 16	~P{221}	294.0
CW4	BLDG 1 OLD	~P{288}	659.1
CW5	ACC	~P{286}	1219.0
CW6	BEDTOWER	~P{535}	1992.0
CW9	LAUNDRY	~P{534}	308.4
TOTAL (ACTUAL, NOT SUM OF ABOVE)			4391.6

Figure 6. Result Matrix for quickly comparing PipeFlo to experimental results.

AUTO HOUSE PUMP DECISION TABLE																	
TOTAL	EFF	# PUMPS	GPM RANGE	MAX EFF	NO. PUMP	PUMP GPM	PUMP HEAD FT	GPM EACH	ID	PIPEFLO	ID	PIPEFLO	QUIRK2	ACTUAL GPM	ACTUAL TDH	ACTUAL RPM	ACTUAL BHP
4489	0	1	-1	84.0	**3**	**1496**	109.4	1496	SCHWP-1	1496.29963899602	~P{504}	0	FXSP	1496	70.5	1545	34.11
4489	0	2	-1					1496	SCHWP-2	1496.29963899602	~P{503}	0	FXSP	1496	70.47	1545	34.11
4489	84	3	1496					1496	SCHWP-3	1496.29963899602	~P{502}	0	FXSP	1496	70.36	1545	34.04
4489	82	4	1122					0	SCHWP-4	-1	~P{474}	1	FXSP	0	0	0	0
													TOTALS	4488	70.5	1545	102.26

Figure 7. Pump Decision Matrix that references pump curves to optimally enable correct number of pumps.

2.4. Software Limitations

Despite PipeFlo being one of the more complete software solutions available on the market, the following limitations were encountered.

- Part-Load Performance. Most of the results of this study are concerned with peak performance. Though the actual AHUs may reset leaving air temperatures or reduce airflow, *the spreadsheet does not*. Most of the field verification was done during the summer months, where this assumption was valid.
- Controls. The model calculates steady-state performance only. Incorporating other strategies may be approximated, but real-time results and control strategies (PID-loops) are not possible.
- Temperatures. The program PipeFlo assumes constant water temperature. This limitation is overcome by using the spreadsheet to calculate the chilled water return temperature of each loop.

3. Model Verification and Discoveries

Through numerous field visits and measurements, the PipeFlo model was meticulously updated with all available hydronic data, including:

- Pump curves with correct impeller trim
- Coil pressure drops
- Valve Cv-values
- Balancing valve settings (Cv-value)
- Chiller and Heat Exchanger pressure drops

3.1. Existing AHU Summary

AIR HANDLING UNIT SCHEDULE						
MARK	HISTORIC MARK	LOOP	SA CFM	OA CFM	DESIGN dT °F	GPM
AH-C	SINCE 1971	B	133000	26600	10	**713**
AH-D	SINCE 1971	B	133000	26600	10	**713**
AH-1	*OR-AH-1*	B	10850	2190	9	**61**
AH-1.1	*OR-AH-2*	B	7300	1760	14	**24**
AH-2	SINCE 198? (AH8, 1971)	B	7360	7360	10	**94**
AH-3	SINCE 1971	B	4500	0	10	**27**
AH-4	SINCE 198? (AH11, 1976; S-21 1949)	B	1200	300	10	**8**
AH-4A	(AH12, 1976; S-19, 1949)	1	1300	1300	10	**21**
AH-5	SINCE 198? (AH7, 1976; S-4, 1949)	1	13400	2000	19	**48**
AH-6	SINCE 1971	B	4000	600	10	**27**
AH-7A	SINCE 1981 (AH12, 1977; S-12, 1949)	1	14000	6600	19	**75**
AH-8	SINCE 1976 (S-5, 1949)	1	4600	4600	12	**41**
AH-8A	SINCE 1995 (NEW)	1	2080	2080	10	**28**
AH-9	SINCE 1976 (S-7, S-20, 1949)	1	9000	1350	19	**31**
AH-10	SINCE 199? (AHU6, 1976; S14, S15, 1949)	1	13900	2350	12	**67**
AH-11	SINCE 1996 (AH2, 1976; S-18 1949)	1	10100	1500	19	**35**
AH-12	SINCE 1996 (AH1, 1976; S-1, S-16, S-17, 1949)	1	25000	3700	19	**78**
AH-13	SINCE 198? (AH4, 1971)	1	4300	640	19	**13**
AH-14	SINCE 1996 (AH10, 1976; S-6, 1949)	1	4200	840	19	**15**
AH-15	SINCE 1996 (AH3, 1976; S-11?, 1949)	1	12600	1890	19	**42**
AH-16	SINCE 1996 (AH4, 1976; S-8, 1949)	1	15500	1550	19	**44**
AH-17	SINCE 1996 (AH5, 1976; S-8, 1949)	1	16500	2500	19	**57**
AH-18	SINCE 1984 (AH/S-10, 1949)	1	18000	2700	19	**58**
AH-19	SINCE 198? (AH15, 1977; S-9, 1949)	1	13400	13400	20	**106**
AH-21	SINCE 198? (AH13, 1977; S-3, 1949)	1	7600	1140	19	**26**
AH-22	SINCE 198? (AH14, 1977; S-2, 1949)	1	4500	675	19	**10**
AH-54	SINCE 200? (AHU-OR#7)	B	2900	2900	11	**46**
AH-24	SINCE 198? (CC-1, 1976)	16	56700	18750	20	**229**
AH-29	SINCE 1983 (AH2, 1971)	L	18000	3600	19	**69**
AH-40	*SINCE 1995 (AH-LAU-1)*	L	6135	6135	17	**57**
AH-41	*SINCE 1995 (AH-LAU-2)*	L	6135	6135	17	**57**
AH-42	*SINCE 1995 (AH-LAU-3)*	L	7300	7300	18	**64**
AH-43	*SINCE 1995 (AH-LAU-4)*	L	7300	7300	18	**64**
AH-58	SINCE 200?	2	3000	1500	10	**29**
AH-59	SINCE 200?	2	4500	4500	10	**67**
AH-60	SINCE 200?	2	3000	3000	10	**44**
AH-44	SINCE 200? (ACC-AHU1, 2007)	8	14620	3370	10	**82**
AH-45	SINCE 200? (ACC-AHU2, 2007)	8	18450	2770	10	**79**
AH-46	SINCE 200? (ACC-AHU3, 2007)	8	46220	7520	10	**233**
AH-47	SINCE 200? (ACC-AHU4, 2007)	8	18810	2820	10	**94**
AH-48	SINCE 200? (ACC-AHU5, 2007)	8	16240	2640	10	**84**
AH-49	SINCE 200? (ACC-AHU6, 2007)	8	32190	4830	10	**152**
AH-50	SINCE 200? (ACC-AHU7, 2007)	8	19150	2870	10	**94**
AH-51	SINCE 200? (ACC-AHU8, 2007)	8	14620	3370	10	**77**
AH-52	SINCE 200? (PROSTHETICS)	8	9000	6000	10	**102**
AH-55	SINCE 2010 (ACC BASEMENT)	8	19450	10500	10	**189**
AH-12B	SINCE 2010 (WOMENS)	B	10300	1550	12	**47**
AH-NEW	CENTRAL PLANT BULDOUT	16	6000	500	20	**17**

Table 1. Existing AHU schedule with 'Ideal GPMs' and Historical Marks

The list of existing air handling units is summarized in Table 1. Each of the critical AHUs identified in the model were field-verified. The coil data was found from submittals, where possible. Other coil data was obtained by physically counting rows, FPI (fins-per-inch), and number of circuits; and then simulating the coil in software (CoilSelectPro by TFE/SMDS). Where control valve Cv-value was critical, the valves were temporarily stripped of insulation and the valve-tag information was cross-referenced.

In gathering the AHU information from as-built documents, the ‘historical mark’ was recorded (second column in Table 1). Many of the AHUs are still commonly referenced by these names.

3.2. Flow Stations

The verification of the model was greatly aided by six recently installed chilled water flow stations (Table 2). Using these flow measurements, data from the BAS, recent TAB data, and ambient air conditions; the software model was verified quickly and often.

FLOW STATIONS		
MARK	LOOP	DESCRIPTION
CW1	2	Supply to Central Plant, Bulding 2, AH58-60, FCUs
CW3	16	Supply to Nursing Home and Plant Expansion, AH-24, AH-NEW
CW4	1	Supply to the Old Hospital, Building 1, Various AH and FCUs
CW5	8	Supply to the ACC, Building 8, AH44-55, FCUs
CW6	B	Supply to the Bedtower, AH-C, AH-D, etc
CW9	L	Supply to Laundry, AH40-43, AH-29, FCUs

Table 2. Flow Station Description (All stations are on Supply, not Return)

3.3. Verification Experiments

After hydronic information was gathered, the software model was verified through several ‘experiments’. The experiments were generally performed in the morning before 11:00am, to avoid any peak charges (APS E-35 plan). The experiments consisted of modifying parameters and/or closing valves, and recording the resulting system changes (at flow stations, Table 2, and at the BAS, Figure 8).

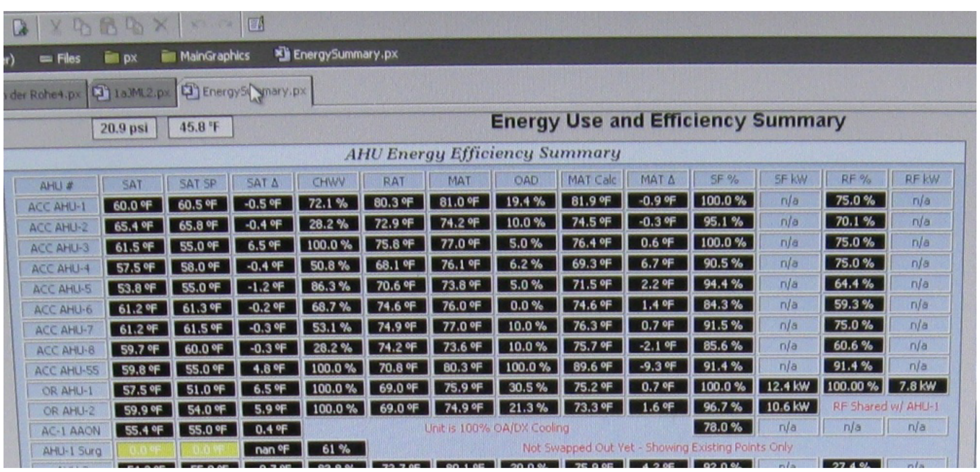

Figure 8. Dozens of camera shots taken of BAS front-end to determine performance.

The VA campus was visited on four occasions

1. Preliminary Model Tuning (7/03/2012). The Central Plant was overridden to (4) different pressures. The resulting flows and responses by the AHUs were recorded. The preliminary model was checked against the responses. The critical AHUs were identified and subsequently investigated.
2. Investigate CW9 Low Flows (7/18/2012). The software model predicted much higher GPMs than recorded. The sensor was preliminarily reported as possibly faulty. The AHUs were found to be at low setting.

3. Locate Old Hospital Blockage (8/24/2012). The Tie-Ins were opened and closed to determine the severity of blockage in the Old Hospital 8” Loop. The flow GPMs were recorded with each adjustment. An artificial blockage (low Cv-value) was created in the software model, and the blockage value was adjusted until the model matched the measured flows. The blockage was found to be quite significant. Refer to Section 3.4 for further information.
4. Performance after Fixing Blockage (9/18/2012). After the blockage was fixed, the Tie-Ins were again opened and closed to determine if the fix had helped. The fix did help significantly, and the model was further tuned.

With each verification experiment, the software model was adjusted closer and closer to the actual system. The *software model now agrees with actual measurements to within 10% accuracy or better*.

3.4. Old Hospital 8” Loop (Building 1)

History of Discoveries

The “old” hospital loop was originally installed in 1949 and has been the target of low flow complaints for the last 4 years. Investigation into possible blockages and under sizing began back in 2009.

Based upon pressure measurements in 2009, the blockage was thought to be in the chilled water return piping. When the exact location could not be discovered, a 6” tie-in was made with the existing 12” mains to ‘back-feed’ the old 8” mains. This modification did improve performance of the system, but remote AHUs still suffered.

A previous Chilled Water Study identified that the blockage was most likely at the Central Plant or just as it entered Building 1. Subsequently, a butterfly valve in the old 8” main was found to be stuck at 90% closed. After that discovery, the hope was that performance would improve. Unfortunately, the performance only slightly improved.

Recent Discoveries

During the course of developing and verifying this Chilled Water Study, it was again observed that flows predicted on the old 8” main did not match the software model (see Appendix G).

Suspecting a possibly blockage, an artificial blockage was created in the software model to find where the actual blockage may be located. From the model and observed AHU performance, the area identified was again in the Central Plant itself. The facility staff was asked to investigate a butterfly valve which may have been the root cause. The staff removed the manual actuator and found that the ‘key’ was damaged (Figure 9). The butterfly valve itself appeared to be closed.

Figure 9. Broken actuator allowed valve to close shut.

The butterfly valve on the chilled water supply was forced to 100% open. Further flow recordings were taken to determine if opening the valve solved the problem. An immediate improvement in performance was observed.

Model Verification with Valve Opened

To determine if performance had indeed improved, the existing 4” and 6” tie-in feeds were opened and closed and flow measurements were recorded (see Table 3, the ‘OLD GPM’ was during monsoon so results are relative).

DESCRIPTION	OLD GPM	NEW GPM	REMARKS
All Bypass Closed	328	370	Bypasses located in basement (8") and below AH-12 (4").
Open Sup Only	467	413	Opened basement (8") bypass. Bypass below AH-12 remained closed.
Open Ret Only	526	365	Opened basement (8") bypass. Bypass below AH-12 remained closed.
All Open	573	418	Bypasses located in basement (8") and below AH-12 (4").

Table 3. Determining performance of fixed 8” main.

The results confirmed that the valve was the blockage on the old 8” main.

- Opening the Tie-Ins actually increased flow, so the old 8” main is no longer ‘back-fed’ but ‘forward-feeds’ the 12” main.
- To correct the software model, the old 8” main piping was made frictionally ‘rough’ (1949 piping). Also, certain branches appear rougher than others. Contractors have reported significant ‘build-up’ in some of the demolished piping, so this may be true.
- Overall, the roughness is expected for this old pipe. *We and the VA may assume that no other blockages exist.*

With the upcoming new loop piping, it will become even more difficult to detect if valves are faulty (since flow will find another path). *We recommend that the VA perform valve inspections annually.*

3.5. Control Valve Issues

Improper balancing valve and control valve selections are often overlooked problems in the HVAC industry. Poor selections can lead to a number of issues: poor control action, non-tight shutoff, flow choking, and even flashing. During the field discovery process, valve information was recorded at the VA Campus. The software model (PipeFlo) is capable of indicating when valves will choke or have poor range. The valve replacements are listed in Section 7.1.

Pressure Differential Limit

Most commercial control valves are limited to an operating differential pressure of 20 PSI. Exceeding this limit leads to poor control (actuator is overcome) or ‘choking’. Choking is often difficult to detect without pressure measurements available. Choking limits the flow through the opening orifice within the valve. Once the critical pressure is met, no further flow increase is possible through the valve. Flashing eventually occurs if the static pressure is reduced below the vapor pressure (uncommon).

A proper balancing valve selection is critical to bring the control valve below its pressure differential limits. The balancing valve can drop excess system pressure, and allow the control valve to operate below 20 PSI differential.

Valve Authority

The size of the control valve (Cv-value) must be chosen to match the ‘load’ being served. The load is the total branch pressure drop, including the coil, piping, accessories, and balancing valve. Good valve authority is achieved when the valve pressure drop equals the load pressure drop at design flow.

Actuator Failure

During previous projects and during this discovery process, several control valve actuators were faulty and replaced (some after only 1 year). While actuators do fail, the rate of failure at the VA Campus is unusual.

- Proportional Feedback is recommended (as opposed to 'Floating'). Knowing from the BAS that the valve is indeed 100% open or closed quickly diagnoses the problem.
- Create better the specifications for Phoenix weather. Most of failed valves were outdoors or in unconditioned penthouses.

3.6. Pump Pressure Differential

The scope of work states that necessary changes be made to achieve *10 PSI differential* at the Central Plant.

In modeling the system, we quickly realized that 10 PSI was not achievable without drastic changes (by drastic, most AHUs and most piping mains). Through several meetings with VA staff, the secondary pumps and pump pressures were discussed. The understanding is that 20 PSI is the upper limit for the peak day. The plant may operate near 10 PSI on non-peak days.

For reference, the current minimum is 36.7 PSI (84% higher than 20 PSI). The minimum PSI achieved occurs at Phase 5, where only 15 PSI is required on a peak day (discussed further in Section 7).

4. Secondary Pumps

There has been much discussion at the VA recently around the topic of pump control. Currently, the VA controls the secondary pumps by δT ('delta' T), which controls pump speed by measuring supply and return temperatures. In addition, the VA maintains minimum and maximum pressure setpoints (measured at the secondary pumps). However, several AHUs remain dissatisfied and the exact setpoints and pressure limits have been questioned.

4.1. Control Methodologies

PUMP CONTROL METHODOLOGIES			
SENARIO	IMMEDIATE SYMPTOM	STEADY-STATE ACTION	
		δT CONTROL	δP CONTROL
Majority of Valves Opening (Morning)	Higher δT, Lower δP, Higher GPM	Pump increase (immediate).	Pump increase (immediate).
Majority of Valves Closing (Night)	No δT change, Higher δP, Lower GPM	Pump decrease *(slow, by reset only, undetected), Note 1*	Pump decrease (immediate). Decrease further by reset only.
One Valve Faults Open (Bad valve or sensors)	Lower δT, Lower δP, Higher GPM	Pump **decrease** (immediate). *Remaining AHUs may suffer, Note 2.*	Pump **increase** (immediate). *Remaining AHUs may be satisfied, Note 3.*
One Valve Faults Closed (Bad valve or sensors)	No δT change, Higher δP, Lower GPM	Pump decrease (*slow, by reset only, undetected*), Note 1	Pump decrease (immediate).
Branch Blockage or Undersized AHU	Higher δT, Higher δP, Lower GPM	Pump **increase** (immediate).	Pump **decrease** (immediate), limited by reset.
Airside Temp Resets Up (Min Reheat cycle)	Higher δT, Higher δP, Lower GPM	Pump **increase** (immediate), over-pumps, Note 4.	Pump **decrease** (immediate).
Airside Temp Resets Down (Dehumid cycle)	Lower δT, Lower δP, Higher GPM	Pump **decrease** (immediate). *Remaining AHUs may suffer.*	Pump **increase** (immediate).
Partial Airside Economizer	Small ±δT, Higher δP, Lower GPM	Pump small in/decrease, *δP unnecessarily high* .	Pump **decrease** (immediate).

Notes:

1. Since the δT remains stable as pump pressure increases past minimum, δT control is poor at detecting decrease in demand. An incremental reset strategy must be used to decrease pump speed. However, because of the incremental nature, the pumps will forever oscillate trying to find the best setpoint.

2. By δT control, a failed AHU has the effect of decreasing pump speed.
   a) If the AHU is remote, this may be desirable, since the pump compensates for the broken valve while maintaining pressure (if remote). However, the fault may go undetected since compensated.
   b) If the AHU is near the pumps, it has the opposite effect and remaining AHUs may suffer.

3. By δP control, a failed AHU has the effect of increasing pump speed. If the pump has adequate head available, the remaining AHUs will not suffer, but energy is wasted.

4. By δT control, a reset up in the leaving air temperature of an AHU (e.g. from 53° to 56°) will also increase the δT (e.g. from 12° to 15°). The δT strategy operates under the assumption that δT can always be made less than setpoint. It responds by increasing pump speed, but will see no immediate change in δT, which will be problematic.

Table 4. Pump Control Methodologies

Assuming that the AHUs are similar and free of faults (broken valves or sensors), both δT and δP strategies should work well. The δT strategy works on the principle that the temperature difference through a cooling coil is a decent indicator of AHU satisfaction. For instance, at different entering air conditions or different air volumes, the temperature through a coil varies by only 1° or 2° degrees when maintaining a constant leaving air temperature (though increases as airside resets, discussed below). The δP strategy works on the principle that pressure differential increases when flow (GPM) is lower. The two methodologies are contrasted in the Table 4.

For both δT and δP control methodologies, it is critical that the following guidelines be followed.

1. Measure δT or δP at each loop and/or multiple locations.
2. Determine the minimum δT or δP of each location, through measurement and verification at design conditions.
3. Do not average the measurements. Control to the greatest setpoint difference.
4. Incorporate incremental pump speed reset strategies (never reset δT!). For δT control, pump speed reset is absolutely required to avoid over-pumping upon decrease in demand. For δP control, incremental reset may be based upon AHU valve position (though leaving water temperature reset is better).
5. Troubleshoot AHUs that miss their leaving air temperature setpoints. This is an indication of a faulty control valve or insufficient pressure (may need to increase setpoints).

4.2. Strengths and Weaknesses

Considering the comments above, both strategies have strengths and weaknesses. Overall, the principles of δT control are mostly sound, but fail to keep AHUs satisfied in practice. The primary weaknesses of δT control are slow responsiveness and dealing with airside resets. However, δT also has the advantage that it directly keeps the system delta-T in check, which saves energy and extends storage capacity but can dissatisfy AHUs. The following Table 5 summarizes the advantages and disadvantages of both approaches.

PUMP CONTROL COMPARE AND CONTRAST		
CONSIDERATION	METHODOLOGY	
	δT CONTROL	δP CONTROL
Energy (Central Plant)	**Best**, but at the cost of dissatisfied AHUs.	*Good*, but may over-pump and lower δT when devices fail.
AHU Satisfaction	Poor, see above discussion.	**Best**, as AHUs having adequate pressure is priority.
Responsiveness	Poor, requires reset when valves close.	**Best**, immediately responds to valves opening and closing.
Airside Reset	Poor, opposite of valve action.	**Best**, responds correctly.
Fault Tolerance	*Good*, will limit over-pumping but may dissatisfy remaining AHUs.	*Good*, will over-pump but keep AHUs satisfied.

Table 5. Comparison and Contrast

The control methodology recommended by this study is a combination--δP control with a lower δT limit (adjusted for high dew point). As demonstrated above, δP control is less complex than δT and has fewer complications, especially concerning airside reset strategies. The additional 'lower δT limit' helps to overcome the shortcomings of δP control and conserve energy by limiting the extent of over-pumping when control valves fault open.

4.3. Example Sequence of Operation

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The controller shall modulate the chilled water pump speeds to maintain each minimum chilled water differential pressure above setpoint at each measured location, respectively. The controller shall limit the chilled water pump speeds to maintain the chilled water temperature delta above the minimum setpoint of 11° (adj). The VFDs *minimum speed shall not drop below 15% (adj). The lead pump shall run anytime the manager is enabled. On dropping chilled water differential pressure, additional pumps shall stage on and modulate to maintain setpoint as follows:*

- *The controller shall modulate the lead pump to maintain pressure setpoint and delta limit.*
- *If the delta is above limit and the lead pump cannot maintain pressure setpoint and its speed rises above 80% (adj), the second pump shall stage on and modulate in unison with the lead pump to maintain pressure setpoint and delta limit.*
- *If the delta is above limit and the two pumps cannot maintain pressure setpoint and their speed rises above 80% (adj), the third pump shall stage on and modulate in unison with the other two pumps to maintain pressure setpoint and delta limit.*
- *If the delta is above limit and the three pumps cannot maintain pressure setpoint and their speed rises above 80% (adj), the fourth pump shall stage on and modulate in unison with the other three pumps to maintain pressure setpoint and delta limit.*

On rising chilled water differential pressure, the pumps shall stage off as follows:

- *If the pressure setpoint is maintained and the speed of the four pumps drops below 60% (adj), the third pump shall stage off.*
- *If the pressure setpoint is maintained and the speed of the remaining three pumps drops below 60% (adj), the second enabled pump shall stage off.*
- *If the pressure setpoint is maintained and the speed of the remaining two pumps drops below 60% (adj), the second enabled pump shall stage off.*

4.4. Sensor Locations and Setpoints

We recommend that a differential pressure assembly be installed at each logical chilled water loop. Loops ‘2’, ‘L’, and ‘16’ are omitted since they are hydraulicly near to the plant. Loop ‘8’ is controlled by its own pump at ‘Phase 0’, and later by the house pumps after the loop is connected. The pressure setpoint may change as future phases are completed. The recommended setpoints are summarized in Table 6.

DELTA-P			
LOOP	LOCATION	PHASE 0 PSID	PHASE 11 PSID
B	12" Mains, before AH-C branch	13.5	11.0
8	6" Mains, before AH-52 branch	15.5	10.0
1	6" Mains, before AH-10 branch	15.5	12.5

Table 6. Recommend Differential Pressure Setpoints

4.5. Reset Strategies

The Central Plant can incrementally reset one of following two quantities (rarely both).

A. Differential Pressure. Conserves pump energy. The system responds by opening control valves to near 100%. The system delta-T changes slightly (e.g. 44.0/64.2 to 44.0/62.8, using CoilSelectPro software).
B. Leaving Water Temperature: Conserves chiller energy by reducing lift (ambient wet-bulb minus leaving water temperature). Again, the system responds by opening control valves to near 100%. However, the system delta-T *does significantly decrease* (e.g. 44.0/64.0 to 47.0/60.9). Since system delta-T is unpredictable, the δT pump control is not easily compatible this reset strategy.

Reset strategy B is recommended and typically has the most energy-savings potential. It also can extend the use of water-side economizer. The disadvantage to strategy B is the drop in entering water temperature (e.g. 64.2 to 60.9 above), which limits the potential load draw from the chilled water storage.

The reset strategy shall incrementally decrease or increase the setpoints based upon AHU control valve positions. The AHU summary schedules, Table 1 and Table 8, list the respective loop that each AHU is installed.

4.6. Sensitivity Analysis

At a meeting at WRL office, the question was asked by James Larson as to *"What was the best outside indicator of pump speed, Relative Humidity, Dew Point, Ambient Temperature, Wet Bulb, or Enthalpy?"* To determine the answer, a sensitivity analysis was done comparing each quantity. Please note, this study is not suggesting that the pumps be controlled from this measured quantity, only that this quantity provides the best indication of where the pumps might operate.

A range of ambient temperatures were chosen, and a common humidity point was chosen at the middle of this range (92°, 30% Rh, 56° Dp, 68° Wb, 33 Btu/lb). Holding the respective four quantities constant, the ambient temperature was varied to 80°, 90°, 100°, and 110°. The PipeFlo model was ran at these (4 by 4 =) 16 conditions to determine the required pump speed. A flat curve represents the best or least-sensitive quantity. A steep curve represents the worst or most-sensitive quantity.

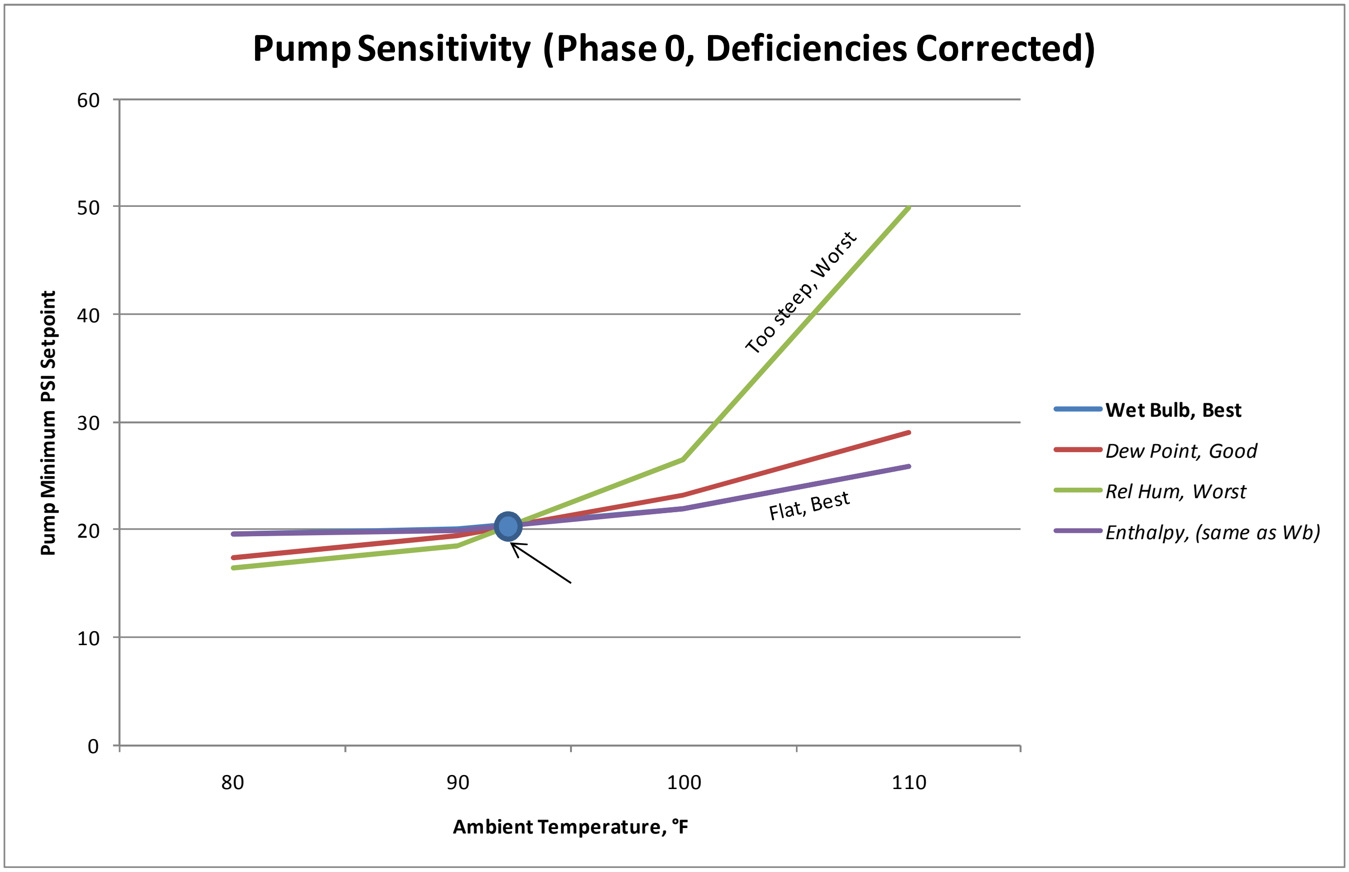

Figure 10. Pump Sensitivity Analysis

As expected, Relative Humidity is the poorest indicator of pump speed. The best indicators are Wet Bulb and Enthalpy (one curve is exactly below the other on Figure 10), which is accurate to within 6 PSI over the 30° range of ambient temperatures.

5. Primary Pumps

Currently, the primary pumps at the VA campus are constant speed pumps. Each pump stages on with each chiller. The chillers are enabled based upon leaving chilled water temperature. There has been discussion of modifying these pumps to variable speed in the near future.

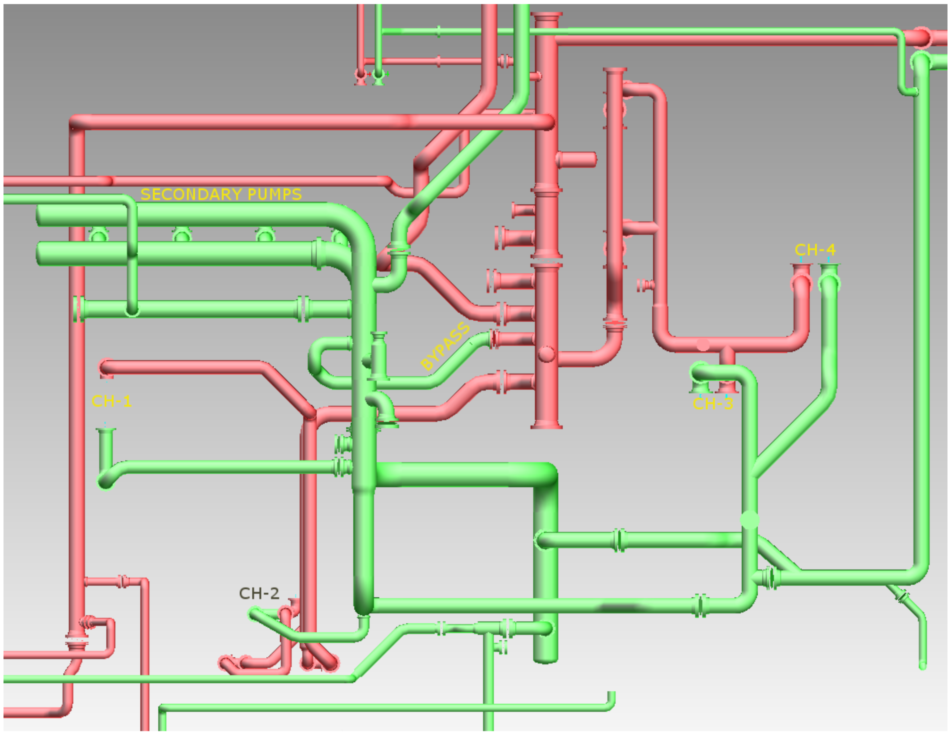

Figure 11. Central Plant with general locations

5.1. Overview of Control Approaches

The manner in which Central Plants are controlled varies widely and is ever evolving. The following paragraphs summarize the many approaches and discuss their advantages and disadvantages.

Primary Pump Control Approaches

- Constant Speed. This is the simplest scheme and will match loads. However, it wastes pump energy and does not maintain a constant leaving water temperature.
- Variable Speed. Most energy efficient, but controls and chiller staging are now more complex. The minimum speed is set for minimum required flow through chillers. The pumps are typically headered together, and speed is varied in unison based upon sensors at the bypass piping (flow or delta-P).

Bypass Piping Approaches (Sensors)

- Flow Meter in Bypass. Purpose is for staging chillers. It operates under the assumption that chiller delta-T is nearly equal to the system delta-T. This is a good assumption in theory, but not always the case in practice. While having a flow meter is common and informative, their use for staging chillers is diminishing.
- Check Valve in Bypass. Purpose is to prevent secondary-flow from exceeding the primary. The idea works well in theory, but does not prevent low delta-T syndrome as some people claim.
- Minimum Flow Valve in Bypass. Purpose is to 1) prevent excess secondary-flow (yet allow if required) and 2) allows minimum flow through chillers. This is presently the best and recommended approach. When the valve is closed, delta-P across the valve may be used to vary the primary pump speed (zero at most efficient operating point).

Chiller Staging Approaches

- Leaving Chilled Water Temperature. When chillers are no longer capable of maintaining the desired temperature, another chiller is enabled.
- Bypass Piping Flow. Assuming primary delta-T equals secondary delta-T, chillers and constant-speed pumps are staged based upon flow. This approach is no longer recommended.
- Explicit Load Matching. Measures GPM and delta-T on both primary-side and secondary-side. It then calculates system load on secondary-side, and stages chillers to meet the system load. This is currently a very common, energy-efficient approach and is immune from cascading the low delta-T syndrome. Also, having these sensors will help simplify control of the chilled water storage.
- Chiller KW. Polls chiller kilowatts from each chiller panel. Stages chillers based upon KW. This approach appears logical and simple, but often requires additional temperature sensors to optimize.
- Optimal Chiller Manager. Third-party controls contractor creates model of system (pump curves and multiple chiller-curves). Knowing the system and energy consumption, the Chiller Manager best decides how to stage chillers and vary pump speeds.

5.2. Recommendations

The Central Plant and all components were modeled in PipeFlo to evaluate the pros and cons of the above approaches. The best strategy was variable-speed primary pumps with minimum flow valve in the bypass. A check valve in the bypass is not recommended.

New Equipment and Piping

- Retrofit primary pumps with VFDs. Replace motors if not VFD-compatible.
- Header (2) primary pumps together (serving CH-1, CH-2). Install (2) 8” isolation valves for CH-1, CH-2.
- Install bypass control valve in 12” bypass piping (Cv = 500).

New Sensors and Locations

- Install flow meter in 20” secondary chilled water supply.
- Install flow meter in 12” bypass (back-calculates primary supply flow).
- Install differential pressure assembly across 12” bypass valve.
- Install differential pressure assemblies across all (4) chillers (detects minimum or maximum flow).
- Install additional temperature sensors, as needed.

New Control Approach

- Bypass Valve Control. Normal mode, closed. Min flow mode, modulate to satisfy minimum chiller flow. Max flow mode, modulate to reduce chiller differential pressure below maximum.
- Pump Control. Normal mode, adjust speed of enabled primary pumps in unison (relative %, adjusted for each chiller) to maintain the bypass differential pressure at 0 PSI (with bypass valve fully-closed). Min flow mode, modulate to maintain the bypass differential pressure at +4 PSI (bypass valve modulates to meet minimum flow of chillers). Max flow mode, modulate to maintain the bypass differential pressure at -4 PSI (bypass valve modulates to below maximum flow of chillers).
- Chiller Staging. The ‘Optimal Chiller Manager’ is recommended for greatest energy savings and best expertise for Chilled Water Storage. If third-party contractor is not desired, then ‘Explicit Load Matching’ is recommended.
- Chilled Water Storage Staging. Essential, the chilled water storage acts as another chiller, but choosing the best run-time hours is critical. The decision of running storage will depend upon time-of-day, instantaneous tonnage (calculated by ‘Explicit Load Matching’), instantaneous system delta-T, available ton-hours in storage, solar energy input from panels, and (optionally) forecasted wet-bulb temperature. If less than 10 hours is expected, the strategy will begin conservatively and then get more aggressive as time passes.

6. Chilled Water Storage Capacity

The chilled water storage system was installed recently under a separate contract (2011 - 2012). The goal of the chilled water storage system was to serve the hospital over the peak period (10 hours, 11am - 9pm), which corresponds to the peak rates charged by utility company (APS E-35).

This study analyzes the capacity of the chilled water storage now and in the future. The current storage capacity is 1.4 million gallons (MGAL) of 41° chilled water. Storage capacity is determined by the peak 'building load profile' and the chilled water storage supply and return temperature difference (delta-T or δT, for short).

6.1. Building Load

The best method to determine building load is to actually record the chiller tons on a peak day. These measurements were not available, so an energy model was created. The VA Campus was modeled in Trane Trace to approximate the building load profile. The gross building square footage and gross wall and window areas were modeled. The approximate people, lighting loads, and plug loads were modeled. The plug load was adjusted until a total CFM of 850000 was achieved (2.2 W/Sqft plug, 1.3 W/Sqft lighting, 150 Sqft/Peop). Default hospital hourly schedules for people, lighting, and plug loads were used. The ventilation air was adjusted to 226000 CFM. The leaving coil temperature was set at 56.8°F. The profile was then incrementally updated with additional areas to model the new buildings and resultant new load profiles.

The resulting 'building load profile' describes the load (Tons) at every hour of the year. The peak 24-hour day of each month is reported (see Appendix D, Appendix E, and Appendix F). However, the goals of the chilled water storage only involve the peak hours, 11am - 9pm. The 'Ton-Hours' reported in the Tables and Charts to follow are totals for the peak hours of each month, with the peak month being July.

6.2. Tank Volume

The current tank volume is 1.4 MGAL. The tank is assumed to have baffles that separate 41° water from return water. The equations used to determine the correct volume are as follows.

$\boldsymbol{\delta U}$ [Ton-hr] * [12000 Btu/(hr-Ton)] = $\boldsymbol{\delta U}$ [Btu] *(Eq 1, Energy Change of System, given as Ton-Hours)*

$\boldsymbol{m}$ [Gal] * [8.33 lbm/gal] = $\boldsymbol{m}$ [lbm] *(Eq 2, Water Mass, given as Gallons)*

$\boldsymbol{\delta u1}$ [Btu/lbm] = $\boldsymbol{\delta U}$ [Btu] / $\boldsymbol{m}$ [lbm] *(Eq 3, Specific Energy Change of System)*

$\boldsymbol{\delta u2}$ [Btu/lbm] = $\boldsymbol{Cv}$ [Btu/(lbm-°F)] * **(Tout - Tin)** [°F] *(Eq 4, Specific Energy Change of Water Storage, Cp = Cv = 1.003*

$\boldsymbol{\delta u2}$ [Btu/lbm] = $\boldsymbol{\delta u1}$ [Btu/lbm] *(Eq 5, Energy Change of System and Storage are Equal)*

$\boldsymbol{m}$ [Gal] = **1436** * $\boldsymbol{\delta U}$ [Ton-hr] / **(Tout - Tin)** [°F] *(Eq 6, Arrange above Eq and solve for Gallons)*

From above, the tank volume is dependent upon 1) delta-T *(Tout – Tin)* and 2) Ton-Hours *(δU)*. The future ideal tank volumes and actual hours are summarized in Table 7.

TANK VOLUME AT PEAK LOAD PROFILE						
PHASE	DESCRIPTION	Delta-T °F	10-HOUR TONS	10-HOUR MGAL	ACTUAL HOURS @ 1.4 MGAL	REMARKS
-	*TANK DESIGN*	*20*	*20792*	*1.49*	*9.4*	*Tank was designed assuming 20° δT.*
-1	CURRENT OCT/2012	11.7	20792	2.55	5.5	Current delta-T is higher than 11.3°F, but is artificially high. Specifically, the Bedtower, Bldg 16, and some units in Bldg 1 have low flow. The low flow allows the chilled water return temperature to rise, while not satisfying the load.
0	CORRECT MISC DEFICIENCIES	12.5	20792	2.39	5.9	Delta-T improved by replacing AH-24 and fixing 'wild' control valves. Replacement of AH-C,D coils is NOT included, but is strongly recommended.
6	EMERGENCY	12.9	23439	2.61	5.4	Near Future (SSIU, REHAB, SPD, MENTAL, and EMERGENCY completed).
11	NEW SURGERY	13.4	27884	2.99	4.7	Distant Future (all planned projects completed).

Table 7. Tank Volume at Peak Load Profile

The current tank volume is not adequate to serve the hospital during the peak-hours in the summer. The hours may be improved by bettering the system delta-T (replacing cooling coils).

Given the 1.4 MGAL limit, the following (3) figures may be used to best strategize the use of the storage. The Figure 12 details current hours-of-use, and Figure 14 details the distant future hours-of-use. The figures do not significantly change since the delta-T is also improved.

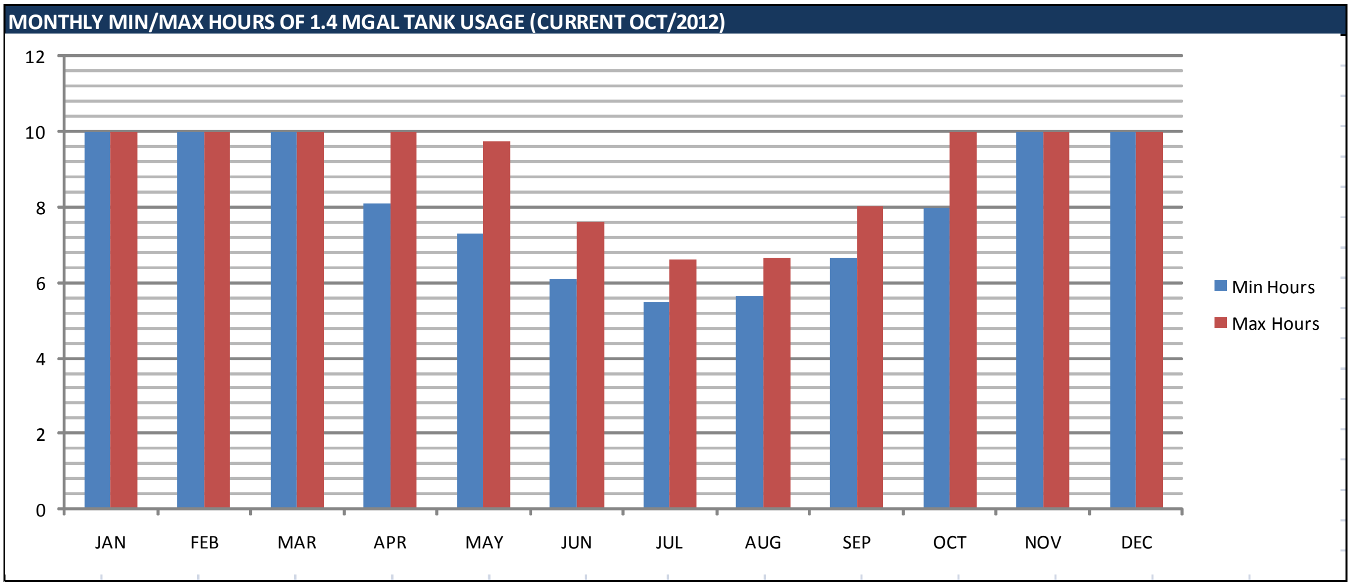

Figure 12. Tank Hourly Usage, Current

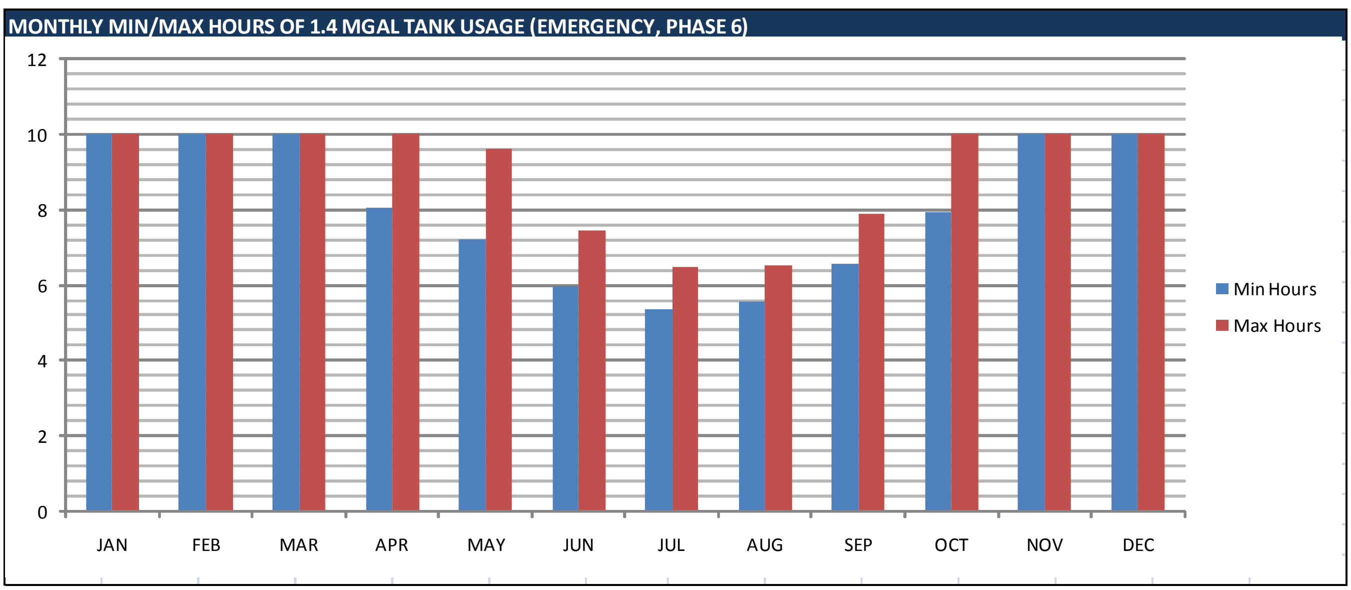

Figure 13. Tank Hourly Usage, Phase 6

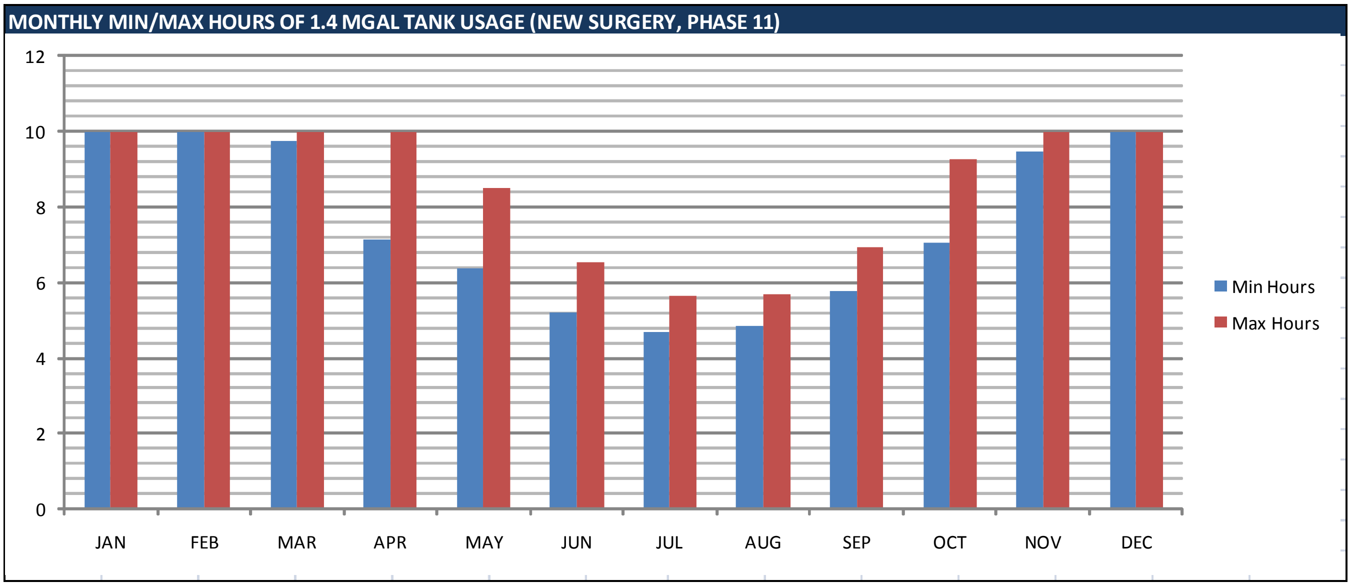

Figure 14. Tank Hourly Usage, Phase 11

During the summer, the storage is not adequate for 10-hours and must be used in conjunction with the plant chillers. For example, in the month of July, 50% of the load may be shed by the storage, while the other 50% must be done by the Central Plant chillers.

The goal expressed by the VA is to strategically enable and disable the chillers based upon solar energy collected by their solar panels. Unfortunately, the amount of solar radiation is unpredictable. The keys for a successful approach will include:

- Fast Chiller Turndown. Variable-speed screw chillers or magnetic-bearing options should be explored. Even a small cloud in an otherwise clear sky can abruptly shade the VA campus.
- Forecasting. As mentioned earlier, wet-bulb is the best indicator of load. Giving the algorithm a daily wet-bulb forecast may improve its performance. Alternatively, adjusting the parameters of the algorithm with a pre-defined monthly schedule may also work well.
- Adaptation. While the core algorithm should be kept simple, the exact parameters will likely be influenced by delta-T, ton-hours, load profile, and other factors that 1) cannot be exactly predicted and 2) change over time as buildings are added or renovated.
- Control Contractor. Many of the items above cannot be adequately described by the conventional "Sequence of Operation". The contractor should have experience implementing adaptive control systems, and specifically have experience with load-shedding strategies.

7. Project Schedule

Construction Documents accompany this study that draft the necessary changes to the chilled water distribution. Specifically, the Construction Documents detail Milestones A, B, D, and E (further discussed below). While these documents describe ‘what’ must occur, the question of ‘when’ they must occur is perhaps more important.

Ten future air handling units will be added to the chilled water system in the near and distant future (Table 8). The first two AHUs are already installed and shall be connected to the chilled water system before the corrections of this study take place. The last four AHUs have yet to be designed, and airflows and GPMs were based upon square-foot approximations.

AIR HANDLING UNIT SCHEDULE						
MARK	HISTORIC MARK	LOOP	SA CFM	OA CFM	DESIGN dT °F	GPM
AH-56	SSIU	B	13400	4000	20	**52**
AH-57	REHAB	B	22400	7700	21	**87**
AH-58	SPD	1	6981	6981	18	**58**
AH-59	MENTAL HEALTH 1	B	41792	16950	12	**201**
AH-60	EMERGENCY	B	19488	3898	20	**66**
AH-61	DENTAL	B	20000	4000	20	**68**
AH-62	LAB (DX CONVERT)	B	17000	17000	20	**126**
AH-63	CLC	B	40000	8000	20	**135**
AH-64	MENTAL HEALTH 2	B	41792	16950	12	**201**
AH-65	NEW SURGERY	B	45000	13500	20	**135**

Table 8. Upcoming New Air Handling Units at VA Campus

The software model of the chilled water system was created such that any of the eleven phases could be dynamically enabled. The software model responds by adjusting chiller loads, adjusting pumps speeds, and enabling the corresponding Milestones.

The Project Schedule and order of Milestones (Table 9) were finalized by running the software model at each phase, following the criteria below.

- Maximum Plant PSI of 20 PSI (install piping mains, correct deficiencies)
- Minimum 20% Chiller Safety Factor (replace chillers)
- Minimum 20% Pump Safety Factor (replace pumps)

PROJECT SCHEDULE													
PHASE					CORRESPONDING MILESTONES (COMPLETED)							REMARKS
PHASE NUMBER	DESCRIPTION	PLANT STATUS AT 0.4% ENTHALPY CONDITION (WHEN COMPLETED)			CORRECT MISC DEFICIENCIES	ROOF PIPING: 12" BACK TO PLANT	CENTRAL PLANT: REPLACE CH-2	ROOF PIPING: WEST BRANCH	ROOF PIPING: EAST BRANCH	CENTRAL PLANT: NEW 900 TON CHILLER	CENTRAL PLANT: REPLACE HOUSE PUMPS	
		CHILLER SF %	PUMPS GPM	PLANT MIN PSI	A	B	C	D	E	F	G	
-1	CURRENT OCT/2012	30%	4520	36.7	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	AH-C/D ASSUMED AT 20% O/A. AH-19,4A,8A DRIVING PSI SETPOINT. LAB & SURG IN ISO MODES.
0	DEFICIENCIES	30%	4316	27.6	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	LAB & SURG IN ISO MODES.
1	SSIU	30%	4366	28.1	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	PROJECT OCCURS IN NEAR FUTURE. IDEALLY 12" ROOF PIPING WOULD OCCUR BEFOREHAND.
2	REHAB	26%	4450	28.7	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	PROJECT OCCURS IN NEAR FUTURE. IDEALLY 12" ROOF PIPING WOULD OCCUR BEFOREHAND.
3	WATER STORAGE	26%	4450	28.7	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	DOES NOT AFFECT SECONDARY SIDE PERFORMANCE.
4	SPD	24%	4583	28.1	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	SURG IN ISO MODE. LAB IN BOOSTER (REQ'D).
5	MENTAL	19%	4756	15.0	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	PLANT MIN PSI IS 28.5 IF 12" NOT INSTALLED.
6	EMERGENCY	24%	4825	15.8	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	INSTALLING WEST BRANCH NOW DOES NOT SIGNIFICANTLY REDUCE MIN PSI.
7	DENTAL	22%	4889	16.0	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	LAB IN PLANT MODE AFTER WEST BRANCH INSTALLED.
8	CLC	17%	5017	16.1	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	CHILLER SAFETY FACTOR (PLANT CAPACITY) IS BELOW 20%.
9	LAB (DX)	40%	5144	16.3	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	CHILLER SAFETY FACTOR WOULD BE 13% W/O NEW CHILLER.
10	NEW MENTAL	35%	5332	16.5	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	NO REMARKS.
11	NEW SURGERY	31%	5460	17.0	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	PUMPS DO NOT NEED REPLACEMENT UNTIL DISTANT FUTURE.

Table 9. Project Schedule and Corresponding Completed Milestones

The cells marked ‘TRUE’ in the table above indicate that the corresponding milestones *must be completed* to achieve the indicated GPM and PSI.

7.1. Milestone A (Correct Deficiencies)

Correcting 'Milestone A' greatly increases AHU satisfaction and reduces secondary pump speeds. For example, to satisfy all AHUs when observed back in July would have required a total of 180 brake-horsepower (BHP) from the pumps (though the plant was never run this way and AHUs were left short of GPM). Correcting these basic deficiencies would allow all AHUs to be satisfied at only 56.2 BHP.

CORRESPONDING MILESTONE SCHEDULE		
MILESTONE	ACTIVITY	ACTIVITY DESCRIPTION
A: CORRECT MISC DEFICIENCIES (AS SOON AS POSSIBLE)	1	AH-C&D: Convert penthouse units from 100% O/A to 20% O/A with R/A. This portion is already being completed by an ongoing project.
	2	AH-52: The piping is greatly undersized and the unit is not meeting setpoint.
	3	AH-24: Coil & valve are not sized for monsoon conditions. Replace coil and valve. Coordinate with upcoming CLC project.
	4	SCHWP-1,2,3,4: Modify controls to restage pumps to provide an efficient operating point. An example sequence and recommendations are included in the Chilled Water Study.
	5	CHWP-221&222: Modify controls to change pump speed based upon Bldg 8.
	6	All AHUs and FCUs: Differential pressure is significantly less than previous. All of the AHUs may require adjustment of their balancing valves.
	7	Misc AHUs: Replace existing AHU control valves and balancing valves with high-quality, correctly-sized assemblies.
	8	Misc FCUs: Several fan coils are without valves and are running 'wild'. Some are even without balancing valves. Known locations: (3) FCUs on 8th floor, (3) FCUs in central plant, (1) FCU in B0119.
	9	Restriction: All restrictions have been found on old 8" main (2 broken valves). However, model predicts that piping is very rough with high head loss.
	10	AH-9,15,16,17,19,21: Adjust the Nexus & TA valves to fully open to reflect actual, lower operating pressure (no danger of choking). Remove valve from AH-19, if present.
	11	AH-19: Replace the cooling coil. The pressure drop thru the coil is high and drives the plant pump speed.

Table 10. Milestone A (Deficiencies)

Each of the milestone activities are further discussed below.

- Activity A.1. These are the largest AHUs on the VA campus (one-third of total load). The current delta-T is low (9° to 11°), and replacement of the coil is also encouraged to better the chilled water storage capacity (see Milestone H).
- Activity A.2. Replace 120' of 2" piping with 3", including control valve and coil connection accessories.
- Activity A.3. The unit was sized in 1976 for hot & arid conditions. The unit also has an undersized 3-way valve, which should also be replaced. An upcoming CLC project may replace or eliminate the unit. Refer to Appendix B.
- Activity A.4. The operating point of the secondary pumps was observed and noted several times during the study. Many times the pumps were observed to be operating well outside of their most efficient operating point. For example, during one visit two pumps were running at only 55% efficiency. Running three pumps instead would have improved pump efficiency and consuming less overall energy.
- Activity A.5. Currently the chilled water pumps in Building 8 operate by the delta-T observed in Building 2. For example, on one occasion the pump was running at only 49% while (2) AHUs in Building 8 were missing their setpoints by 6°. In summary, the Building 8 pumps should run based upon Building 8. Recommend that a remote differential pressure assembly be installed, and that the pumps operate to maintain a minimum pressure.
- Activity A.6. After 'Milestone A' work is constructed, TAB agent shall 1) override house pumps to 20 PSI (measured at plant), 2) measure GPM at each air handling unit, and 3) adjust balancing valve as required to meet flow requirements.
- Activity A.7. Even after 'Milestone A' is completed, some valves will experience differential pressures that may cause 'choking' or overflow (low delta-T). Remove and replace with valves equal to Belimo PICV, rated for 50 PSI differential pressure. Units include IRM AH-6, SPD AH-8, Lab AH-7*, Central Plant AH-29*, AH-58, AH-59, AH-60, and Laundry AH-40, AH-41, AH-42, AH-43 (* Coordinate, valves may already be replaced by ongoing projects).

- Activity A.8. The three fan coils on the 8th floor require control valves to help low delta-T. The three fan coils located within the Central Plant are without control valves (two above York chillers, one above Trane & McQuay chillers). With the high water pressures, the coil velocities are high and one fan coil actually allows flow to bypasses the chillers. The one fan coil in B0119 only has a balancing valve installed, and the room is kept too cold. Also, it is stealing flow away from AH-18 and AH-19, which have been problematic."
- Activity A.9. As mentioned earlier, this Chilled Water Study was successful in that it has identified (2) blockage locations. However, the model still does not match all of the measured pressures. The current explanation is pipe roughness and build-up. The piping was installed in 1949, and some demolished piping has shown significant build-up (other areas are clean of build-up, however).
- Activity A.10. The latest TAB report from the AHU replacement project balanced the AHUs with the plant running at 30 PSI. All of the balancing valves are now artificially high, and need to be dialed back down. The same can likely be said about other AHUs across the VA campus. If after the corrections an AHU or FCU is not satisfied, the first action should be further opening the balancing valve. Most of the observed balancing valves are manual (no spring devices), which will not adapt well to the future, lower differential pressure (15 PSI)."
- Activity A.11. While the coil is technically capable of the air-side performance, the water-side pressure drop is high. Recommend replacement of coil (5.3' @ 102 GPM). An example re-selection is included in the Appendix C.

7.2. Milestones B through G (New Loop and Chillers)

New piping shall be installed to improve distribution and reduce the pipe velocities and pressures at the Central Plant (Figure 15, Appendix H). New chillers shall be installed if capacity is less than 20%.

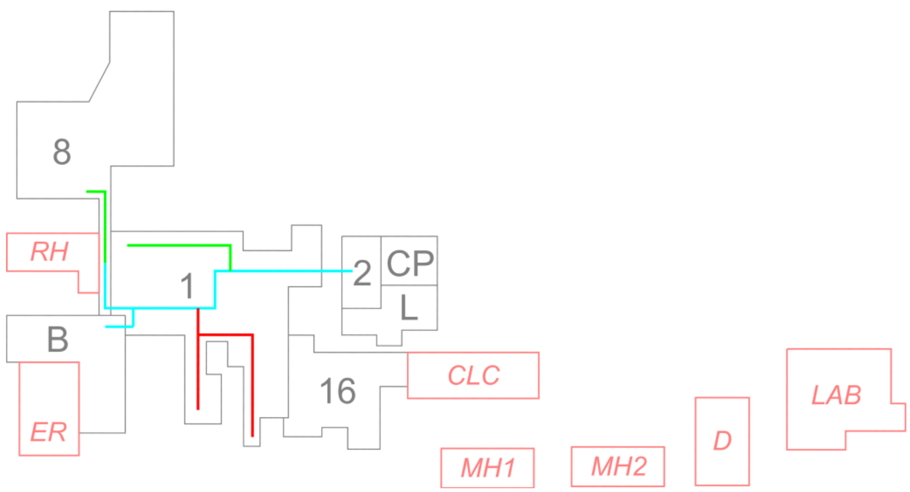

Figure 15. New Distribution Improvements (cyan = Main 12", green = West Branch, red = East Branch)

CORRESPONDING MILESTONE SCHEDULE		
MILESTONE	ACTIVITY	ACTIVITY DESCRIPTION
B: ROOF PIPING, 12"	1	Loop: Install to keep plant pressure less than 20 psi.
C: CENTRAL PLANT, REPLACE CH-2 (NOT IN SCOPE)	1	Chiller Capacity: Campus tonnage exceeds current capacity + 20%. Replace existing chiller with upsized new.
D: ROOF PIPING, WEST BRANCH	1	Loop: Required to keep plant pressure less than 20 psi.
	2	CHWP-221&222: Install full-size bypass with check-valve.
E: ROOF PIPING, EAST BRANCH	1	Loop: Required to keep plant pressure less than 20 psi.
F: CENTRAL PLANT, NEW 900 TON CHILLER (NOT IN SCOPE)	1	Chiller Capacity: Campus tonnage exceeds current capacity + 20%. Install new chiller.
G: CENTRAL PLANT, REPLACE HOUSE PUMPS (NOT IN SCOPE)	1	SCHWP-1,2,3,4: If campus gpm exceeds current capacity + 20%.

Table 11. Milestones B through G

Each of the milestone activities are further discussed below.

- Activity B.1. Installing the 12" line greatly reduces the required differential pressure at the secondary pumps.
- Activity C.1. New 700-ton chiller to replace existing 500-ton. Note that this recommendation does not consider the benefit of chilled water storage.
- Activity D.1. Connect Bldg 8 as well. Within Bldg 8, upsize existing 6" to 8" and cross-connect the 6" and 4" mains to feed AH-55.
- Activity D.2. The booster pumps are now only occasionally required. The control sequence shall allow the pumps to be disabled if differential pressure is exceeded by adjustable amount with pumps at 20%.
- Activity E.1. Connect West AHUs to further reduce pump pressures.
- Activity F.1. Note that this recommendation does not consider the chilled water storage.
- Activity G.1. Replacement of these pumps is not yet required for the foreseeable future.

7.3. Milestone H (Energy Improvements)

The final set of milestones are energy improvement projects that the VA should keep in mind for the future. These milestones are not drafted in the Construction Documents, as they are not critical to reducing the pump pressures. Activities H.1, H.2, and H.4 may be done at any time.

CORRESPONDING MILESTONE SCHEDULE		
MILESTONE	ACTIVITY	ACTIVITY DESCRIPTION
H: OTHER ENERGY IMPROVEMENTS (NOT IN SCOPE)	1	HX-1,2: Dedicated pump can only provide 70% of design GPM.
	2	AH-C&D: The delta-T is poor.
	3	Central Plant: Once 20 degree delta is achieved, repipe chillers in series for better efficiency.
	4	Central Plant: Install variable speed drives for primary pumps. Replace P-186 (operates past curve, inefficient). Install minimum flow valve on bypass.

Table 12. Milestone H (Energy Improvements)

Each of the milestone activities are further discussed below.

- Activity H.1, Low Priority. The current heat exchangers are undersized. Worse yet, the pumps only deliver 70% of the design GPM. However, currently the VA does not operate the heat exchanger often.

- Activity H.2, High Priority. These are the largest AHUs on the VA campus (one-third of total load). The current delta-T is low (9° to 11°). Modifying these coils not only improves delta-T, but also reduces pumping requirements. Option #1: Install coils downstream of current coils. Additional space is now available in the airstream since the fans were replaced with fan-wall. Option #2: Replace existing cooling coils with new; refer to Appendix A.
- Activity H.3, Low Priority. Even in the distant future, the delta-T approaches only 13.4°F. When the delta-T is at least 16°, this reconfiguration is recommended.
- Activity H.4, High Priority. Current pumps consistently over-pump and increase the leaving water temperature.

Appendix A. Example Coil Selections for AH-C&D

RAHN INDUSTRIES
2630 Pacific Park Drive
Whittier, CA 90601
Phone: 1-800-421-7070
Fax: 562.908.0744
sales@rahnindustries.com

Customer:	VA Hospital
Project:	Chilled Water Study
Date:	11/12/12
Item:	Replace Coil (section) of AH-C&D
Prepared By:	CAS

WATER COOLING COIL

USER INPUT - COIL

Tube Diameter	0.625 in
Tube Pattern	1.5 in x 1.299 in - Staggered
Fin Height	91.5 in
Fin Length	120.0 in
Rows Deep	8
Tube Thickness/Mat'l	0.02 in CU
Tube Smooth/Rifle	Smooth
Fin Thickness/Mat'l	0.006 in CU
Fin Type (F,W,LC,LV,S)	V-Waffle
Fin Pitch	11.0 fins/in
No. of Circuits	61

USER INPUT - AIR

Barometric Pressure	14.7 psia
Inlet Dry Bulb Temp	82.5 F
Inlet Wet Bulb Temp	66.9 F
Air Flow Rate (Std.)	33,250 SCFM

USER INPUT - FLUID

Fluid Type	Water
Liquid Flow Rate	135.0 gpm
Liquid Inlet Temp	44.0 F

WARNING/NOTE

1)
2)
3)
4)
5)
6)

CALCULATED OUTPUT - COIL

Rows High	61
Face Area	76.25 ft^2
Total Tubes / TPC	488 / 8
Headers Same/Opposite	Same Side

CALCULATED OUTPUT - AIR

Air Mass Flow Rate	2490.9 lbm/min
Inlet Air Flow Rate	34,248 ACFM
Air Side Re No.	4,661
Inlet Relative Humidity	44.4 %
Inlet Dew Point Temp	58.7 F
Inlet (Act.) Face Velocity	449 fpm
Outlet Dry Bulb Temp	53.0 F
Outlet Wet Bulb Temp	52.9 F
Outlet Air Flow Rate	32,409 ACFM
Air-side Pressure Loss	0.67 in. w.g.

CALCULATED OUTPUT - FLUID

Avg. Fluid-side Vel.	2.47 fps
Outlet Temperature	65.0 F
Fluid Mass Flow Rate	1126.0 lbm/min
Fluid-side Re No.	9,497
Inlet Header Size	5.0 in
Outlet Header Size	5.0 in
Fluid-side Press. Loss	7.06 ft

CALCULATED OUTPUT - PERFORMANCE

Total Capacity	1,421,252 Btu/hr
Sensible Capacity	1,075,161 Btu/hr
Latent Capacity	346,092 Btu/hr

RAHN INDUSTRIES PART NO.

C W 91.5-120-8-11-- -

CoilSelectPro (Version 1.1.2)
Project File:

RHAN INDUSTRIES

Appendix B. Example Coil Selections for AH-24 (Nursing)

RAHN INDUSTRIES
2630 Pacific Park Drive
Whittier, CA 90601
Phone: 1-800-421-7070
Fax: 562.908.0744
sales@rahnindustries.com

Customer:	VA Hospital
Project:	Chilled Water Study
Date:	11/12/12
Item:	Replace Coil (section) of AH-24
Prepared By:	CAS

WATER COOLING COIL

USER INPUT - COIL	
Tube Diameter	0.625 in
Tube Pattern	1.5 in x 1.299 in - Staggered
Fin Height	42.0 in
Fin Length	66.0 in
Rows Deep	8
Tube Thickness/Mat'l	0.02 in CU
Tube Smooth/Rifle	Smooth
Fin Thickness/Mat'l	0.008 in AL
Fin Type (F,W,LC,LV,S)	V-Waffle
Fin Pitch	9.0 fins/in
No. of Circuits	28

USER INPUT - AIR	
Barometric Pressure	14.7 psia
Inlet Dry Bulb Temp	82.5 F
Inlet Wet Bulb Temp	66.9 F
Air Flow Rate (Std.)	10,177 SCFM

USER INPUT - FLUID	
Fluid Type	Water
Liquid Flow Rate	46.0 gpm
Liquid Inlet Temp	44.0 F

WARNING/NOTE
1)
2)
3)
4)
5)
6)

CALCULATED OUTPUT - COIL	
Rows High	28
Face Area	19.25 ft^2
Total Tubes / TPC	224 / 8
Headers Same/Opposite	Same Side

CALCULATED OUTPUT - AIR	
Air Mass Flow Rate	762.4 lbm/min
Inlet Air Flow Rate	10,482 ACFM
Air Side Re No.	5,740
Inlet Relative Humidity	44.4 %
Inlet Dew Point Temp	58.7 F
Inlet (Act.) Face Velocity	545 fpm
Outlet Dry Bulb Temp	55.0 F
Outlet Wet Bulb Temp	54.6 F
Outlet Air Flow Rate	9,959 ACFM
Air-side Pressure Loss	0.79 in. w.g.

CALCULATED OUTPUT - FLUID	
Avg. Fluid-side Vel.	1.83 fps
Outlet Temperature	60.9 F
Fluid Mass Flow Rate	383.7 lbm/min
Fluid-side Re No.	6,831
Inlet Header Size	3.5 in
Outlet Header Size	3.5 in
Fluid-side Press. Loss	2.9 ft

CALCULATED OUTPUT - PERFORMANCE	
Total Capacity	386,040 Btu/hr
Sensible Capacity	304,653 Btu/hr
Latent Capacity	81,387 Btu/hr

RAHN INDUSTRIES PART NO.
C W 42-66-8-9-- -

CoilSelectPro (Version 1.1.2)
Project File:

RHAN INDUSTRIES

Appendix C. Example New Coil Selections for AH-19 (Kitchen)

RAHN INDUSTRIES
2630 Pacific Park Drive
Whittier, CA 90601
Phone: 1-800-421-7070
Fax: 562.908.0744
sales@rahnindustries.com

Customer:	VA Hospital
Project:	Chilled Water Study
Date:	09/25/12
Item:	Replacement Coil of AH-19
Prepared By:	CAS

WATER COOLING COIL

USER INPUT - COIL

Tube Diameter	0.50 in
Tube Pattern	1.5 in x 1.299 in - Staggered
Fin Height	51.0 in
Fin Length	84.0 in
Rows Deep	8
Tube Thickness/Mat'l	0.02 in CU
Tube Smooth/Rifle	Smooth
Fin Thickness/Mat'l	0.008 in CU
Fin Type (F,W,LC,LV,S)	V-Waffle
Fin Pitch	12.0 fins/in
No. of Circuits	68

USER INPUT - AIR

Barometric Pressure	14.118 psia
Inlet Dry Bulb Temp	95.0 F
Inlet Wet Bulb Temp	76.0 F
Air Flow Rate (Std.)	12,171 SCFM

USER INPUT - FLUID

Fluid Type	Water
Liquid Flow Rate	100.0 gpm
Liquid Inlet Temp	44.0 F

WARNING/NOTE

1)
2)
3)
4)
5)
6)

CALCULATED OUTPUT - COIL

Rows High	34
Face Area	29.75 ft^2
Total Tubes / TPC	272 / 4
Headers Same/Opposite	Same Side

CALCULATED OUTPUT - AIR

Air Mass Flow Rate	911.8 lbm/min
Inlet Air Flow Rate	13,400 ACFM
Air Side Re No.	3,195
Inlet Relative Humidity	42.6 %
Inlet Dew Point Temp	68.8 F
Inlet (Act.) Face Velocity	450 fpm
Outlet Dry Bulb Temp	52.9 F
Outlet Wet Bulb Temp	52.9 F
Outlet Air Flow Rate	12,393 ACFM
Air-side Pressure Loss	0.4 in. w.g.

CALCULATED OUTPUT - FLUID

Avg. Fluid-side Vel.	2.61 fps
Outlet Temperature	63.4 F
Fluid Mass Flow Rate	834.1 lbm/min
Fluid-side Re No.	7,860
Inlet Header Size	4.0 in
Outlet Header Size	4.0 in
Fluid-side Press. Loss	5.12 ft

CALCULATED OUTPUT - PERFORMANCE

Total Capacity	965,549 Btu/hr
Sensible Capacity	558,861 Btu/hr
Latent Capacity	406,687 Btu/hr

RAHN INDUSTRIES PART NO.

B W 51-84-8-12-- -

CoilSelectPro (Version 1.1.2)
Project File:

RHAN INDUSTRIES

Appendix D. Building Load Profile - Current (October 2012)

BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	51.1	41.5	0	20.1	0	68.9	0	68.9	0	68.9	0	68.9
2	50.3	41.0	0	0.0	0	48.0	0	48.0	0	48.0	0	48.0
3	49.3	40.7	-181,009	0.0	0	22.9	0	22.9	0	22.9	0	22.9
4	48.4	39.9	-318,774	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	47.5	39.5	-354,817	0.0	-284,241	0.0	-284,241	0.0	-284,241	0.0	-284,241	0.0
6	46.9	39.2	-242,601	0.0	-464,289	0.0	-464,289	0.0	-464,289	0.0	-464,289	0.0
7	46.7	38.9	0	0.0	0	83.2	0	83.2	0	83.2	0	83.2
8	46.7	39.0	0	104.6	0	393.5	0	393.6	0	393.6	0	393.6
9	49.8	40.5	0	693.2	0	456.3	0	456.4	0	456.4	0	456.4
10	53.7	42.5	0	801.7	0	565.8	0	565.8	0	565.8	0	565.8
11	57.3	43.8	0	902.6	0	650.0	0	663.6	0	663.6	0	650.0
12	60.1	45.2	0	1,001.7	0	729.7	0	749.4	0	749.4	0	729.8
13	62.0	46.0	0	1,031.6	0	746.7	0	772.4	0	772.4	0	746.7
14	64.2	47.2	0	1,117.8	0	844.2	0	870.0	0	870.0	0	844.3
15	65.7	47.7	0	1,157.4	0	903.7	0	929.6	0	929.6	0	903.8
16	65.9	47.7	0	1,183.6	0	943.6	0	969.6	0	969.6	0	943.7
17	65.6	47.8	0	1,223.1	0	1,015.4	0	1,027.6	0	1,027.6	0	1,015.4
18	62.7	46.9	0	1,226.7	0	1,017.5	0	1,023.6	0	1,023.7	0	1,017.5
19	60.6	45.9	0	1,124.6	0	945.8	0	945.9	0	945.9	0	945.8
20	58.2	45.1	0	1,013.7	0	849.1	0	849.2	0	849.3	0	849.2
21	56.4	44.4	0	934.1	0	788.2	0	788.3	0	788.3	0	788.2
22	54.8	43.5	0	725.5	0	594.7	0	594.8	0	594.8	0	594.7
23	53.5	42.8	0	417.7	0	298.2	0	298.2	0	298.2	0	298.2
24	52.5	42.2	0	281.2	0	168.7	0	168.7	0	168.7	0	168.7

February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	55.7	48.1	0	303.0	0	186.4	0	186.0	0	186.0	0	186.0
2	54.4	47.9	0	274.4	0	153.5	0	153.1	0	153.1	0	153.1
3	53.5	47.4	0	251.0	0	128.6	0	128.2	0	128.2	0	128.2
4	52.7	47.1	0	233.5	0	106.5	0	106.2	0	106.1	0	106.1
5	51.9	46.6	0	225.6	0	86.3	0	86.0	0	86.0	0	86.0
6	51.4	46.3	0	232.0	0	71.7	0	71.5	0	71.4	0	71.4
7	50.9	45.9	0	383.6	0	189.0	0	188.7	0	188.6	0	188.6
8	52.0	46.3	0	747.8	0	531.5	0	530.9	0	530.8	0	530.8
9	55.0	47.6	0	827.1	0	605.0	0	604.5	0	604.4	0	604.4
10	58.4	49.1	0	943.7	0	712.2	0	711.7	0	711.6	0	711.6
11	62.1	50.5	0	1,043.0	0	800.5	0	813.9	0	813.8	0	800.1
12	65.2	51.5	0	1,138.2	0	879.6	0	899.0	0	899.0	0	879.2
13	67.4	52.4	0	1,167.5	0	898.2	0	923.7	0	923.7	0	897.9
14	69.2	52.6	0	1,254.1	0	981.5	0	1,007.2	0	1,007.2	0	981.3
15	70.0	52.7	0	1,296.2	0	1,019.6	0	1,045.4	0	1,045.4	0	1,019.5
16	70.5	52.6	0	1,327.4	0	1,066.6	0	1,092.5	0	1,092.5	0	1,066.6
17	70.0	52.3	0	1,377.2	0	1,135.7	0	1,147.8	0	1,147.8	0	1,135.7
18	68.1	51.5	0	1,408.0	0	1,185.4	0	1,191.3	0	1,191.3	0	1,185.3
19	65.3	50.9	0	1,306.2	0	1,103.4	0	1,103.3	0	1,103.3	0	1,103.4
20	63.4	50.5	0	1,182.7	0	1,017.3	0	1,017.2	0	1,017.2	0	1,017.2
21	61.6	50.4	0	1,072.4	0	931.5	0	931.3	0	931.3	0	931.4
22	60.0	49.9	0	855.1	0	732.8	0	732.6	0	732.6	0	732.6
23	58.7	49.4	0	540.0	0	431.5	0	431.4	0	431.4	0	431.5
24	57.5	49.0	0	399.7	0	296.3	0	296.2	0	296.2	0	296.2

Project Name:
Dataset Name: Water Storage.trc

TRACE® 700 v6.2.7 calculated at 04:11 PM on 10/01/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

March	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	59.1	48.6	0	371.0	0	269.8	0	270.0	0	270.0	0	270.0
2	57.7	48.0	0	342.5	0	234.3	0	234.5	0	234.5	0	234.5
3	56.2	47.4	0	320.0	0	196.6	0	196.7	0	196.7	0	196.7
4	55.1	46.8	0	302.7	0	168.9	0	168.9	0	168.9	0	168.9
5	54.3	46.4	0	295.0	0	145.7	0	145.8	0	145.8	0	145.8
6	53.8	46.0	0	300.9	0	132.9	0	132.9	0	132.9	0	132.9
7	53.7	45.7	0	451.6	0	257.6	0	257.7	0	257.7	0	257.7
8	56.0	46.8	0	836.5	0	645.2	0	645.3	0	645.3	0	645.3
9	59.8	48.5	0	921.2	0	740.4	0	740.6	0	740.6	0	740.6
10	62.9	49.6	0	1,035.1	0	843.7	0	843.9	0	843.9	0	843.9
11	65.5	50.7	0	1,108.6	0	889.9	0	903.8	0	903.8	0	890.1
12	67.8	51.4	0	1,192.5	0	948.1	0	968.2	0	968.2	0	948.4
13	69.4	51.9	0	1,215.9	0	946.8	0	973.1	0	973.1	0	947.1
14	70.8	52.3	0	1,300.9	0	1,020.7	0	1,047.1	0	1,047.1	0	1,021.0
15	71.5	52.6	0	1,343.3	0	1,056.4	0	1,082.8	0	1,082.8	0	1,056.7
16	72.3	52.8	0	1,376.4	0	1,113.8	0	1,140.4	0	1,140.4	0	1,114.2
17	72.1	52.7	0	1,429.1	0	1,191.2	0	1,203.8	0	1,203.9	0	1,191.5
18	71.2	52.6	0	1,472.8	0	1,274.3	0	1,280.8	0	1,280.8	0	1,274.6
19	69.4	52.1	0	1,378.5	0	1,214.1	0	1,214.4	0	1,214.4	0	1,214.3
20	67.2	51.5	0	1,257.6	0	1,124.4	0	1,124.6	0	1,124.6	0	1,124.5
21	65.3	50.7	0	1,139.8	0	1,028.7	0	1,028.8	0	1,028.8	0	1,028.8
22	63.4	50.0	0	921.1	0	821.2	0	821.3	0	821.3	0	821.3
23	62.0	49.8	0	605.1	0	516.5	0	516.5	0	516.5	0	516.5
24	60.5	49.3	0	464.8	0	372.8	0	372.9	0	372.9	0	372.9

April	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	68.5	50.2	0	568.8	0	501.9	0	502.0	0	502.1	0	502.1
2	66.5	49.5	0	529.5	0	451.7	0	451.9	0	451.9	0	451.9
3	64.4	48.5	0	498.4	0	399.4	0	399.5	0	399.6	0	399.6
4	62.8	47.8	0	474.8	0	358.0	0	358.1	0	358.1	0	358.1
5	61.6	47.4	0	464.0	0	325.4	0	325.5	0	325.5	0	325.5
6	60.5	46.8	0	472.4	0	296.6	0	296.6	0	296.6	0	296.6
7	61.5	47.4	0	646.4	0	458.5	0	459.0	0	459.2	0	459.2
8	66.4	49.6	0	1,057.7	0	912.4	0	913.8	0	914.0	0	914.0
9	71.3	51.5	0	1,165.0	0	1,039.8	0	1,041.1	0	1,041.4	0	1,041.4
10	75.6	53.3	0	1,286.0	0	1,157.1	0	1,158.4	0	1,158.6	0	1,158.6
11	78.7	54.4	0	1,374.1	0	1,206.2	0	1,221.2	0	1,221.4	0	1,207.5
12	81.2	55.1	0	1,481.1	0	1,265.3	0	1,286.5	0	1,286.7	0	1,266.6
13	83.5	55.6	0	1,527.1	0	1,279.3	0	1,305.9	0	1,306.1	0	1,279.7
14	85.1	56.0	0	1,630.4	0	1,358.2	0	1,384.5	0	1,384.5	0	1,358.4
15	86.5	56.2	0	1,681.8	0	1,408.6	0	1,434.9	0	1,434.9	0	1,408.8
16	87.1	56.4	0	1,711.7	0	1,457.9	0	1,484.2	0	1,484.2	0	1,458.0
17	86.3	56.0	0	1,754.8	0	1,521.6	0	1,534.0	0	1,534.0	0	1,521.7
18	85.1	55.4	0	1,789.4	0	1,595.6	0	1,602.0	0	1,602.0	0	1,595.8
19	82.6	54.4	0	1,692.4	0	1,535.7	0	1,536.0	0	1,536.0	0	1,535.9
20	80.1	53.8	0	1,555.3	0	1,443.7	0	1,444.0	0	1,444.0	0	1,443.8
21	77.0	53.0	0	1,413.9	0	1,323.6	0	1,323.8	0	1,323.8	0	1,323.7
22	74.4	52.1	0	1,163.7	0	1,093.4	0	1,093.6	0	1,093.6	0	1,093.5
23	72.4	51.6	0	829.3	0	773.0	0	773.0	0	773.1	0	773.0
24	70.8	51.1	0	674.7	0	626.1	0	626.1	0	626.1	0	626.1

Project Name:
Dataset Name: Water Storage.trc

TRACE® 700 v6.2.7 calculated at 04:11 PM on 10/01/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

May	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	75.7	56.1	0	751.9	0	681.0	0	681.3	0	681.3	0	681.3
2	73.7	55.3	0	714.6	0	630.2	0	630.5	0	630.5	0	630.5
3	71.6	54.6	0	685.1	0	578.4	0	578.5	0	578.5	0	578.5
4	70.3	54.2	0	662.8	0	543.0	0	543.0	0	543.0	0	543.0
5	68.9	53.5	0	652.7	0	507.2	0	507.2	0	507.2	0	507.2
6	67.8	53.0	0	660.3	0	479.5	0	479.5	0	479.5	0	479.5
7	70.1	54.0	0	847.0	0	679.9	0	679.9	0	679.8	0	679.8
8	74.1	55.3	0	1,264.2	0	1,122.4	0	1,122.3	0	1,122.3	0	1,122.3
9	78.2	56.7	0	1,369.5	0	1,235.0	0	1,235.0	0	1,235.0	0	1,235.0
10	81.5	58.0	0	1,470.7	0	1,316.9	0	1,316.9	0	1,316.9	0	1,316.9
11	84.6	58.7	0	1,541.7	0	1,356.2	0	1,370.2	0	1,370.2	0	1,356.4
12	87.2	59.4	0	1,635.0	0	1,409.1	0	1,429.3	0	1,429.3	0	1,409.4
13	89.3	59.8	0	1,672.4	0	1,417.7	0	1,444.1	0	1,444.1	0	1,418.0
14	91.3	60.2	0	1,771.2	0	1,507.2	0	1,533.8	0	1,533.8	0	1,507.6
15	92.3	60.2	0	1,820.5	0	1,551.7	0	1,578.5	0	1,578.6	0	1,552.2
16	92.3	60.1	0	1,851.4	0	1,592.5	0	1,619.4	0	1,619.4	0	1,593.0
17	91.9	59.7	0	1,902.3	0	1,667.5	0	1,680.4	0	1,680.5	0	1,668.0
18	91.1	59.4	0	1,950.9	0	1,758.9	0	1,765.8	0	1,765.9	0	1,759.5
19	89.1	58.5	0	1,876.1	0	1,723.9	0	1,724.7	0	1,724.8	0	1,724.5
20	86.2	58.2	0	1,748.6	0	1,625.4	0	1,626.0	0	1,626.1	0	1,625.9
21	82.5	57.8	0	1,608.8	0	1,486.2	0	1,486.6	0	1,486.6	0	1,486.5
22	80.5	57.3	0	1,348.0	0	1,255.7	0	1,255.9	0	1,256.0	0	1,255.9
23	79.3	57.0	0	1,012.8	0	947.6	0	947.7	0	947.7	0	947.6
24	77.7	56.6	0	858.3	0	799.7	0	799.7	0	799.7	0	799.7

June	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	87.4	61.7	0	1,072.3	0	969.0	0	968.5	0	968.4	0	968.4
2	85.7	61.4	0	1,035.7	0	922.5	0	922.0	0	921.9	0	921.9
3	84.4	61.3	0	1,007.3	0	886.7	0	886.1	0	886.2	0	886.2
4	82.6	60.9	0	985.9	0	842.2	0	841.9	0	842.0	0	842.0
5	81.4	60.4	0	976.0	0	810.7	0	810.6	0	810.6	0	810.6
6	80.9	60.1	0	983.3	0	793.9	0	793.7	0	793.7	0	793.7
7	82.8	60.8	0	1,171.0	0	990.9	0	990.9	0	991.0	0	991.0
8	86.3	61.9	0	1,588.7	0	1,427.3	0	1,427.5	0	1,427.7	0	1,427.7
9	90.0	63.0	0	1,690.9	0	1,534.8	0	1,535.0	0	1,535.1	0	1,535.1
10	93.6	63.9	0	1,784.8	0	1,623.7	0	1,623.8	0	1,624.0	0	1,624.0
11	96.7	64.7	0	1,848.2	0	1,666.3	0	1,680.0	0	1,680.1	0	1,666.3
12	99.1	65.2	0	1,934.5	0	1,717.2	0	1,736.9	0	1,737.0	0	1,716.9
13	101.4	65.8	0	1,966.6	0	1,731.6	0	1,757.3	0	1,757.3	0	1,731.2
14	103.0	66.2	0	2,062.3	0	1,811.7	0	1,837.5	0	1,837.4	0	1,811.3
15	103.9	66.3	0	2,109.8	0	1,853.3	0	1,879.2	0	1,879.1	0	1,853.0
16	104.2	66.4	0	2,143.3	0	1,898.7	0	1,924.6	0	1,924.5	0	1,898.4
17	103.8	66.2	0	2,200.6	0	1,977.0	0	1,988.9	0	1,988.8	0	1,976.7
18	102.8	65.9	0	2,259.7	0	2,068.3	0	2,074.0	0	2,074.0	0	2,068.0
19	100.5	65.1	0	2,194.6	0	2,030.3	0	2,029.9	0	2,029.9	0	2,030.0
20	97.7	64.2	0	2,080.9	0	1,929.0	0	1,928.6	0	1,928.6	0	1,928.7
21	95.2	63.7	0	1,935.4	0	1,811.2	0	1,810.9	0	1,810.8	0	1,810.9
22	92.8	63.4	0	1,669.4	0	1,561.8	0	1,561.6	0	1,561.6	0	1,561.6
23	90.8	63.0	0	1,333.1	0	1,235.3	0	1,235.2	0	1,235.2	0	1,235.2
24	89.3	62.5	0	1,178.3	0	1,085.3	0	1,085.2	0	1,085.2	0	1,085.2

Project Name:
Dataset Name: Water Storage.trc

TRACE® 700 v6.2.7 calculated at 04:11 PM on 10/01/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

July	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	91.2	69.1	0	1,186.1	0	1,217.7	0	1,244.9	0	1,245.7	0	1,245.7
2	89.6	68.8	0	1,162.1	0	1,192.2	0	1,214.9	0	1,215.5	0	1,215.6
3	88.3	68.5	0	1,144.2	0	1,168.3	0	1,187.4	0	1,187.9	0	1,187.9
4	86.9	68.4	0	1,134.3	0	1,150.5	0	1,166.6	0	1,167.0	0	1,167.0
5	86.3	68.5	0	1,141.2	0	1,150.5	0	1,164.4	0	1,164.8	0	1,164.8
6	85.8	68.2	0	1,150.2	0	1,134.6	0	1,146.3	0	1,146.7	0	1,146.7
7	86.9	68.6	0	1,335.9	0	1,327.5	0	1,341.4	0	1,341.8	0	1,341.8
8	89.4	69.3	0	1,759.3	0	1,779.5	0	1,798.8	0	1,799.4	0	1,799.4
9	92.7	69.9	0	1,849.8	0	1,854.1	0	1,869.7	0	1,870.1	0	1,870.1
10	95.7	70.6	0	1,941.7	0	1,923.9	0	1,936.3	0	1,936.6	0	1,936.6
11	98.5	71.0	0	1,989.6	0	1,933.3	0	1,959.6	0	1,959.9	0	1,943.0
12	101.1	71.4	0	2,062.7	0	1,969.9	0	2,003.1	0	2,003.3	0	1,977.4
13	102.9	71.6	0	2,081.7	0	1,952.9	0	1,992.4	0	1,992.6	0	1,958.5
14	104.6	71.7	0	2,162.9	0	2,020.1	0	2,058.4	0	2,058.5	0	2,024.0
15	105.8	71.9	0	2,203.3	0	2,057.0	0	2,095.5	0	2,095.6	0	2,060.2
16	106.6	72.1	0	2,236.3	0	2,113.6	0	2,152.5	0	2,152.5	0	2,116.2
17	106.1	71.7	0	2,293.1	0	2,181.8	0	2,204.7	0	2,204.7	0	2,184.1
18	104.0	71.2	0	2,355.8	0	2,251.8	0	2,266.4	0	2,266.5	0	2,253.7
19	101.9	70.4	0	2,288.1	0	2,196.0	0	2,202.2	0	2,202.2	0	2,197.5
20	99.7	70.0	0	2,196.4	0	2,115.7	0	2,120.4	0	2,120.4	0	2,116.9
21	97.5	70.0	0	2,061.6	0	2,033.4	0	2,037.0	0	2,037.0	0	2,034.3
22	95.8	69.7	0	1,803.9	0	1,807.0	0	1,809.4	0	1,809.4	0	1,807.6
23	93.9	69.6	0	1,474.2	0	1,488.2	0	1,489.8	0	1,489.8	0	1,488.6
24	92.9	69.7	0	1,329.9	0	1,362.6	0	1,363.7	0	1,363.7	0	1,362.9

August	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	88.3	68.0	0	1,156.5	0	1,132.5	0	1,157.3	0	1,158.1	0	1,158.1
2	86.6	67.5	0	1,127.0	0	1,099.6	0	1,120.3	0	1,120.9	0	1,120.9
3	85.8	67.4	0	1,105.8	0	1,085.6	0	1,103.1	0	1,103.6	0	1,103.6
4	84.4	67.2	0	1,095.9	0	1,068.4	0	1,083.2	0	1,083.6	0	1,083.6
5	83.3	67.0	0	1,090.4	0	1,049.7	0	1,062.2	0	1,062.5	0	1,062.5
6	82.5	66.8	0	1,098.7	0	1,035.2	0	1,045.7	0	1,046.0	0	1,046.0
7	82.8	67.1	0	1,282.8	0	1,206.8	0	1,219.6	0	1,220.0	0	1,220.0
8	85.8	67.9	0	1,711.4	0	1,656.9	0	1,675.1	0	1,675.6	0	1,675.6
9	89.3	68.8	0	1,793.0	0	1,749.1	0	1,763.9	0	1,764.3	0	1,764.3
10	92.6	69.5	0	1,882.8	0	1,835.6	0	1,847.6	0	1,847.9	0	1,847.9
11	95.3	70.1	0	1,930.3	0	1,860.5	0	1,886.5	0	1,886.8	0	1,869.9
12	97.6	70.4	0	1,997.9	0	1,901.2	0	1,934.2	0	1,934.4	0	1,908.6
13	99.4	70.6	0	2,008.5	0	1,884.9	0	1,924.3	0	1,924.5	0	1,890.4
14	100.9	70.9	0	2,092.4	0	1,962.2	0	2,001.3	0	2,001.4	0	1,966.0
15	101.7	71.0	0	2,132.1	0	1,992.8	0	2,031.3	0	2,031.3	0	1,995.9
16	102.3	70.8	0	2,157.5	0	2,031.2	0	2,070.0	0	2,070.1	0	2,033.8
17	102.5	70.8	0	2,210.9	0	2,115.7	0	2,138.5	0	2,138.6	0	2,118.0
18	102.0	70.5	0	2,260.3	0	2,205.3	0	2,219.9	0	2,219.9	0	2,207.3
19	100.1	69.8	0	2,180.6	0	2,148.8	0	2,154.8	0	2,154.9	0	2,150.3
20	97.6	69.3	0	2,062.0	0	2,053.3	0	2,057.8	0	2,057.9	0	2,054.4
21	95.1	68.9	0	1,940.7	0	1,951.0	0	1,954.5	0	1,954.5	0	1,951.9
22	92.6	68.5	0	1,702.1	0	1,714.6	0	1,717.0	0	1,717.0	0	1,715.2
23	91.1	68.1	0	1,370.2	0	1,382.4	0	1,384.0	0	1,384.0	0	1,382.8
24	89.5	67.9	0	1,225.7	0	1,239.2	0	1,240.2	0	1,240.3	0	1,239.5

Project Name:
Dataset Name: Water Storage.trc

TRACE® 700 v6.2.7 calculated at 04:11 PM on 10/01/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

September	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	81.6	62.1	0	937.0	0	819.0	0	828.6	0	830.0	0	830.1
2	80.5	61.6	0	905.1	0	787.9	0	796.4	0	797.6	0	797.6
3	79.2	61.2	0	879.7	0	754.9	0	766.1	0	767.1	0	767.2
4	78.0	60.9	0	860.7	0	725.4	0	738.2	0	739.1	0	739.1
5	76.8	60.7	0	851.9	0	698.6	0	711.5	0	712.3	0	712.3
6	76.3	60.7	0	858.8	0	691.2	0	702.5	0	703.2	0	703.3
7	76.5	60.7	0	1,013.7	0	825.8	0	840.3	0	841.2	0	841.2
8	79.2	61.4	0	1,410.2	0	1,234.2	0	1,257.0	0	1,258.4	0	1,258.4
9	83.0	62.8	0	1,505.6	0	1,344.2	0	1,364.5	0	1,365.8	0	1,365.8
10	86.5	63.9	0	1,629.7	0	1,467.9	0	1,486.2	0	1,487.4	0	1,487.4
11	89.8	64.9	0	1,709.8	0	1,532.1	0	1,562.6	0	1,563.6	0	1,548.5
12	92.5	65.4	0	1,800.9	0	1,594.0	0	1,629.6	0	1,630.5	0	1,607.9
13	94.9	65.6	0	1,832.2	0	1,606.8	0	1,647.0	0	1,647.7	0	1,617.9
14	96.6	66.0	0	1,925.7	0	1,691.1	0	1,731.1	0	1,731.7	0	1,701.0
15	97.7	66.1	0	1,972.3	0	1,740.6	0	1,777.1	0	1,777.6	0	1,746.3
16	97.6	66.0	0	2,000.6	0	1,778.7	0	1,811.9	0	1,812.3	0	1,780.3
17	96.5	65.5	0	2,042.1	0	1,826.7	0	1,841.4	0	1,841.8	0	1,827.0
18	95.2	65.3	0	2,068.2	0	1,880.0	0	1,890.2	0	1,890.6	0	1,880.3
19	92.3	64.1	0	1,965.5	0	1,786.3	0	1,786.7	0	1,786.7	0	1,786.5
20	89.8	64.0	0	1,839.8	0	1,684.4	0	1,691.1	0	1,691.3	0	1,687.9
21	87.3	63.7	0	1,724.9	0	1,588.2	0	1,595.3	0	1,595.5	0	1,592.7
22	86.0	63.5	0	1,501.1	0	1,392.6	0	1,397.7	0	1,397.8	0	1,395.8
23	84.3	63.0	0	1,179.7	0	1,075.3	0	1,078.2	0	1,078.3	0	1,077.2
24	82.6	62.6	0	1,034.9	0	927.9	0	929.9	0	929.9	0	929.2

October	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	71.6	56.7	0	691.2	0	572.2	0	572.1	0	572.1	0	572.1
2	70.1	56.0	0	659.2	0	534.4	0	534.2	0	534.3	0	534.3
3	68.8	55.6	0	633.6	0	501.7	0	501.8	0	501.9	0	501.9
4	67.5	55.0	0	613.9	0	468.9	0	469.0	0	469.0	0	469.0
5	66.7	54.5	0	605.3	0	447.3	0	447.3	0	447.3	0	447.3
6	66.2	54.1	0	612.6	0	432.0	0	431.8	0	431.8	0	431.8
7	65.9	53.9	0	767.7	0	554.4	0	554.3	0	554.3	0	554.3
8	69.0	55.2	0	1,159.4	0	961.3	0	961.8	0	961.9	0	961.9
9	73.3	57.0	0	1,257.5	0	1,073.7	0	1,074.3	0	1,074.3	0	1,074.3
10	77.2	58.4	0	1,386.6	0	1,199.1	0	1,199.6	0	1,199.7	0	1,199.7
11	81.0	59.6	0	1,475.0	0	1,275.5	0	1,289.8	0	1,289.9	0	1,276.1
12	83.9	60.6	0	1,569.5	0	1,347.4	0	1,367.9	0	1,367.9	0	1,348.0
13	86.1	61.5	0	1,603.8	0	1,367.0	0	1,393.5	0	1,393.6	0	1,367.5
14	87.8	61.6	0	1,701.0	0	1,453.7	0	1,480.3	0	1,480.4	0	1,454.2
15	88.4	61.8	0	1,748.6	0	1,492.2	0	1,518.9	0	1,518.9	0	1,492.7
16	87.6	61.7	0	1,772.1	0	1,507.3	0	1,534.0	0	1,534.1	0	1,507.8
17	86.3	61.1	0	1,800.5	0	1,537.7	0	1,550.4	0	1,550.5	0	1,538.1
18	83.5	60.2	0	1,793.5	0	1,534.2	0	1,540.8	0	1,540.9	0	1,534.6
19	80.9	59.7	0	1,680.9	0	1,448.1	0	1,448.5	0	1,448.5	0	1,448.4
20	78.6	59.2	0	1,560.3	0	1,360.5	0	1,360.8	0	1,360.9	0	1,360.7
21	76.9	58.4	0	1,470.9	0	1,298.2	0	1,298.5	0	1,298.5	0	1,298.4
22	75.3	57.9	0	1,251.7	0	1,103.2	0	1,103.4	0	1,103.4	0	1,103.3
23	74.2	57.5	0	933.6	0	806.4	0	806.5	0	806.5	0	806.5
24	72.9	56.9	0	790.4	0	669.0	0	669.0	0	669.0	0	669.0

Project Name: TRACE® 700 v6.2.7 calculated at 04:11 PM on 10/01/2012
Dataset Name: Water Storage.trc Alternative - 1 System Load Profiles report Page 5 of 6

BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

November	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	59.7	48.4	0	399.7	0	278.5	0	278.7	0	278.7	0	278.7
2	58.4	47.7	0	370.4	0	247.1	0	247.3	0	247.4	0	247.4
3	57.4	47.3	0	347.0	0	221.2	0	221.4	0	221.4	0	221.4
4	56.3	46.7	0	328.9	0	194.8	0	195.0	0	195.0	0	195.0
5	55.7	46.3	0	320.9	0	177.9	0	178.0	0	178.1	0	178.1
6	54.9	46.2	0	327.6	0	158.9	0	158.9	0	158.9	0	158.9
7	54.6	45.9	0	480.5	0	279.3	0	279.4	0	279.4	0	279.4
8	56.1	46.8	0	847.6	0	632.9	0	633.0	0	633.0	0	633.0
9	60.3	48.7	0	930.0	0	737.2	0	737.3	0	737.3	0	737.3
10	64.5	50.6	0	1,048.1	0	868.3	0	868.4	0	868.4	0	868.4
11	68.1	51.8	0	1,146.2	0	955.6	0	969.5	0	969.5	0	955.7
12	70.9	52.9	0	1,238.3	0	1,027.6	0	1,047.6	0	1,047.6	0	1,027.8
13	73.1	53.7	0	1,268.5	0	1,044.0	0	1,070.2	0	1,070.2	0	1,044.2
14	74.3	54.2	0	1,360.4	0	1,120.7	0	1,146.9	0	1,146.9	0	1,120.9
15	75.5	54.6	0	1,402.4	0	1,169.5	0	1,195.8	0	1,195.8	0	1,169.7
16	75.3	54.3	0	1,420.9	0	1,194.7	0	1,221.1	0	1,221.1	0	1,195.0
17	74.0	53.7	0	1,438.7	0	1,219.2	0	1,231.7	0	1,231.7	0	1,219.4
18	70.7	52.5	0	1,430.9	0	1,203.1	0	1,209.5	0	1,209.5	0	1,203.3
19	68.4	51.7	0	1,328.2	0	1,124.4	0	1,124.6	0	1,124.6	0	1,124.6
20	65.9	50.8	0	1,227.8	0	1,039.1	0	1,039.3	0	1,039.3	0	1,039.3
21	64.3	50.3	0	1,151.3	0	985.3	0	985.5	0	985.5	0	985.4
22	63.0	49.9	0	941.5	0	798.5	0	798.6	0	798.6	0	798.6
23	61.7	49.1	0	630.5	0	500.5	0	500.6	0	500.6	0	500.6
24	60.4	48.6	0	492.0	0	365.0	0	365.1	0	365.1	0	365.0

December	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	49.2	42.1	0	140.0	0	22.5	0	23.2	0	23.3	0	23.3
2	48.2	41.7	0	114.1	-57,270	0.0	-57,270	0.0	-57,270	0.0	-57,270	0.0
3	47.5	41.4	0	93.1	-261,204	0.0	-261,204	0.0	-261,204	0.0	-261,204	0.0
4	46.5	40.9	0	77.4	-562,988	0.0	-562,988	0.0	-562,988	0.0	-562,988	0.0
5	45.7	40.5	0	70.2	-807,459	0.0	-807,459	0.0	-807,459	0.0	-807,459	0.0
6	45.3	40.3	0	76.1	-938,891	0.0	-938,891	0.0	-938,891	0.0	-938,891	0.0
7	44.8	39.9	0	224.9	0	39.6	0	40.0	0	40.1	0	40.1
8	45.3	40.3	0	577.8	0	362.6	0	363.4	0	363.5	0	363.5
9	48.5	41.7	0	641.2	0	431.4	0	432.1	0	432.2	0	432.2
10	51.8	43.1	0	744.5	0	529.9	0	530.6	0	530.7	0	530.8
11	55.1	44.7	0	838.2	0	611.3	0	625.7	0	625.8	0	612.1
12	57.7	45.8	0	929.0	0	682.9	0	703.5	0	703.6	0	683.7
13	59.9	46.4	0	953.9	0	701.0	0	727.7	0	727.8	0	701.8
14	61.5	47.1	0	1,038.1	0	783.8	0	810.6	0	810.7	0	784.6
15	62.6	47.3	0	1,076.1	0	827.6	0	854.6	0	854.7	0	828.4
16	63.0	47.5	0	1,096.6	0	868.4	0	895.5	0	895.6	0	869.1
17	61.9	47.2	0	1,121.6	0	907.4	0	920.6	0	920.7	0	908.1
18	59.5	46.7	0	1,122.7	0	918.5	0	925.4	0	925.5	0	919.0
19	57.2	46.4	0	1,029.3	0	842.5	0	843.2	0	843.3	0	842.9
20	55.0	45.4	0	937.3	0	765.0	0	765.6	0	765.6	0	765.4
21	54.0	44.9	0	868.4	0	724.1	0	724.6	0	724.6	0	724.4
22	52.5	44.0	0	666.6	0	535.0	0	535.4	0	535.4	0	535.2
23	51.2	43.1	0	363.8	0	240.9	0	241.2	0	241.2	0	241.1
24	50.0	42.7	0	230.9	0	108.1	0	108.3	0	108.3	0	108.2

Project Name: TRACE® 700 v6.2.7 calculated at 04:11 PM on 10/01/2012
Dataset Name: Water Storage.trc Alternative - 1 System Load Profiles report Page 6 of 6

Appendix E. Building Load Profile - Phase 6, After Emergency Clinic

BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	51.1	41.5	0	0.0	0	17.8	0	17.8	0	17.8	0	17.8
2	50.3	41.0	-271,615	0.0	-82,680	0.0	-82,680	0.0	-82,680	0.0	-82,680	0.0
3	49.3	40.7	-502,660	0.0	-441,902	0.0	-441,902	0.0	-441,902	0.0	-441,902	0.0
4	48.4	39.9	-673,833	0.0	-773,854	0.0	-773,854	0.0	-773,854	0.0	-773,854	0.0
5	47.5	39.5	-724,879	0.0	-1,103,015	0.0	-1,103,015	0.0	-1,103,015	0.0	-1,103,015	0.0
6	46.9	39.2	-601,203	0.0	-1,314,961	0.0	-1,314,961	0.0	-1,314,961	0.0	-1,314,961	0.0
7	46.7	38.9	-294,876	0.0	0	21.2	0	21.2	0	21.2	0	21.2
8	46.7	39.0	0	21.2	0	355.0	0	355.1	0	355.1	0	355.1
9	49.8	40.5	0	539.4	0	432.0	0	432.0	0	432.0	0	432.0
10	53.7	42.5	0	839.3	0	563.4	0	563.4	0	563.5	0	563.5
11	57.3	43.8	0	963.7	0	667.8	0	682.6	0	682.6	0	667.9
12	60.1	45.2	0	1,083.1	0	763.3	0	784.6	0	784.6	0	763.4
13	62.0	46.0	0	1,123.6	0	787.6	0	815.4	0	815.4	0	787.6
14	64.2	47.2	0	1,222.8	0	899.8	0	927.7	0	927.7	0	899.9
15	65.7	47.7	0	1,270.7	0	970.8	0	998.8	0	998.8	0	970.9
16	65.9	47.7	0	1,301.9	0	1,017.7	0	1,045.8	0	1,045.8	0	1,017.8
17	65.6	47.8	0	1,342.6	0	1,096.3	0	1,109.5	0	1,109.5	0	1,096.4
18	62.7	46.9	0	1,335.5	0	1,087.6	0	1,094.2	0	1,094.3	0	1,087.6
19	60.6	45.9	0	1,210.6	0	998.8	0	999.0	0	999.0	0	998.9
20	58.2	45.1	0	1,076.8	0	882.1	0	882.2	0	882.2	0	882.1
21	56.4	44.4	0	982.2	0	809.6	0	809.7	0	809.7	0	809.7
22	54.8	43.5	0	750.1	0	595.6	0	595.6	0	595.6	0	595.6
23	53.5	42.8	0	412.6	0	271.7	0	271.7	0	271.7	0	271.7
24	52.5	42.2	0	261.5	0	129.0	0	129.0	0	129.0	0	129.0

February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	55.7	48.1	0	293.1	0	155.5	0	155.3	0	155.2	0	155.2
2	54.4	47.9	0	259.3	0	116.8	0	116.5	0	116.4	0	116.4
3	53.5	47.4	0	231.7	0	87.5	0	87.2	0	87.1	0	87.1
4	52.7	47.1	0	211.0	0	61.5	0	61.2	0	61.2	0	61.2
5	51.9	46.6	0	201.7	0	37.7	0	37.5	0	37.4	0	37.4
6	51.4	46.3	0	209.1	0	20.5	0	20.3	0	20.3	0	20.3
7	50.9	45.9	0	374.2	0	145.3	0	145.0	0	144.9	0	144.9
8	52.0	46.3	0	771.7	0	517.0	0	516.5	0	516.4	0	516.4
9	55.0	47.6	0	868.5	0	606.8	0	606.3	0	606.2	0	606.2
10	58.4	49.1	0	1,008.8	0	735.9	0	735.4	0	735.4	0	735.4
11	62.1	50.5	0	1,131.6	0	845.5	0	860.0	0	859.9	0	845.1
12	65.2	51.5	0	1,245.6	0	940.3	0	961.4	0	961.4	0	940.0
13	67.4	52.4	0	1,284.8	0	966.7	0	994.4	0	994.4	0	966.5
14	69.2	52.6	0	1,384.5	0	1,062.3	0	1,090.2	0	1,090.2	0	1,062.2
15	70.0	52.7	0	1,435.5	0	1,108.2	0	1,136.2	0	1,136.2	0	1,108.1
16	70.5	52.6	0	1,472.7	0	1,163.4	0	1,191.6	0	1,191.6	0	1,163.4
17	70.0	52.3	0	1,525.7	0	1,238.8	0	1,252.0	0	1,252.0	0	1,238.8
18	68.1	51.5	0	1,550.8	0	1,286.1	0	1,292.7	0	1,292.7	0	1,286.2
19	65.3	50.9	0	1,426.0	0	1,185.2	0	1,185.2	0	1,185.2	0	1,185.2
20	63.4	50.5	0	1,276.8	0	1,080.6	0	1,080.5	0	1,080.5	0	1,080.6
21	61.6	50.4	0	1,145.3	0	978.4	0	978.3	0	978.3	0	978.3
22	60.0	49.9	0	902.7	0	758.0	0	757.8	0	757.8	0	757.9
23	58.7	49.4	0	556.4	0	428.4	0	428.3	0	428.3	0	428.3
24	57.5	49.0	0	400.7	0	278.8	0	278.7	0	278.7	0	278.7

Project Name:
Dataset Name: Water Storage-Subtotal.trc

TRACE® 700 v6.2.7 calculated at 10:58 AM on 10/30/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

March	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	59.1	48.6	0	372.8	0	253.8	0	254.0	0	254.0	0	254.0
2	57.7	48.0	0	339.1	0	212.0	0	212.2	0	212.2	0	212.2
3	56.2	47.4	0	312.5	0	167.6	0	167.7	0	167.7	0	167.7
4	55.1	46.8	0	292.1	0	134.9	0	135.0	0	135.0	0	135.0
5	54.3	46.4	0	283.0	0	107.6	0	107.7	0	107.7	0	107.7
6	53.8	46.0	0	289.8	0	92.5	0	92.5	0	92.5	0	92.5
7	53.7	45.7	0	453.9	0	225.9	0	226.1	0	226.1	0	226.1
8	56.0	46.8	0	876.4	0	651.1	0	651.3	0	651.3	0	651.3
9	59.8	48.5	0	979.9	0	766.8	0	767.0	0	767.0	0	767.0
10	62.9	49.6	0	1,117.5	0	891.7	0	891.9	0	891.9	0	891.9
11	65.5	50.7	0	1,209.9	0	951.6	0	966.8	0	966.8	0	951.9
12	67.8	51.4	0	1,310.7	0	1,022.1	0	1,043.9	0	1,043.9	0	1,022.4
13	69.4	51.9	0	1,343.0	0	1,025.2	0	1,053.7	0	1,053.7	0	1,025.6
14	70.8	52.3	0	1,441.0	0	1,109.8	0	1,138.4	0	1,138.4	0	1,110.1
15	71.5	52.6	0	1,492.6	0	1,152.8	0	1,181.5	0	1,181.6	0	1,153.2
16	72.3	52.8	0	1,532.0	0	1,220.4	0	1,249.2	0	1,249.2	0	1,220.7
17	72.1	52.7	0	1,588.4	0	1,305.5	0	1,319.2	0	1,319.2	0	1,305.8
18	71.2	52.6	0	1,628.8	0	1,392.3	0	1,399.4	0	1,399.4	0	1,392.6
19	69.4	52.1	0	1,512.6	0	1,316.6	0	1,317.0	0	1,317.0	0	1,316.9
20	67.2	51.5	0	1,366.0	0	1,207.5	0	1,207.8	0	1,207.8	0	1,207.7
21	65.3	50.7	0	1,225.2	0	1,093.2	0	1,093.5	0	1,093.5	0	1,093.4
22	63.4	50.0	0	980.6	0	862.4	0	862.5	0	862.5	0	862.5
23	62.0	49.8	0	633.1	0	528.5	0	528.6	0	528.6	0	528.5
24	60.5	49.3	0	477.3	0	369.0	0	369.0	0	369.0	0	369.0

April	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	68.5	50.2	0	606.5	0	527.8	0	527.9	0	528.0	0	528.0
2	66.5	49.5	0	560.1	0	468.6	0	468.8	0	468.8	0	468.8
3	64.4	48.5	0	523.3	0	407.0	0	407.1	0	407.1	0	407.1
4	62.8	47.8	0	495.4	0	358.2	0	358.3	0	358.3	0	358.3
5	61.6	47.4	0	482.7	0	319.7	0	319.8	0	319.8	0	319.8
6	60.5	46.8	0	492.4	0	285.7	0	285.7	0	285.7	0	285.7
7	61.5	47.4	0	684.4	0	463.4	0	463.6	0	463.7	0	463.7
8	66.4	49.6	0	1,137.0	0	966.6	0	968.2	0	968.4	0	968.4
9	71.3	51.5	0	1,268.1	0	1,120.4	0	1,121.9	0	1,122.1	0	1,122.1
10	75.6	53.3	0	1,414.8	0	1,262.0	0	1,263.3	0	1,263.5	0	1,263.5
11	78.7	54.4	0	1,524.9	0	1,325.5	0	1,341.8	0	1,342.0	0	1,327.0
12	81.2	55.1	0	1,653.2	0	1,397.7	0	1,420.1	0	1,420.3	0	1,398.5
13	83.5	55.6	0	1,712.5	0	1,419.1	0	1,447.4	0	1,447.4	0	1,419.3
14	85.1	56.0	0	1,832.4	0	1,509.8	0	1,538.2	0	1,538.3	0	1,510.0
15	86.5	56.2	0	1,894.8	0	1,570.3	0	1,598.8	0	1,598.8	0	1,570.5
16	87.1	56.4	0	1,930.5	0	1,628.1	0	1,656.6	0	1,656.6	0	1,628.3
17	86.3	56.0	0	1,975.9	0	1,697.0	0	1,710.5	0	1,710.5	0	1,697.2
18	85.1	55.4	0	2,005.5	0	1,773.0	0	1,779.9	0	1,779.9	0	1,773.1
19	82.6	54.4	0	1,886.1	0	1,697.7	0	1,698.0	0	1,698.0	0	1,697.9
20	80.1	53.8	0	1,720.1	0	1,585.7	0	1,585.9	0	1,585.9	0	1,585.8
21	77.0	53.0	0	1,551.0	0	1,442.6	0	1,442.8	0	1,442.8	0	1,442.7
22	74.4	52.1	0	1,268.5	0	1,184.6	0	1,184.7	0	1,184.7	0	1,184.7
23	72.4	51.6	0	898.6	0	831.7	0	831.7	0	831.7	0	831.7
24	70.8	51.1	0	725.6	0	668.0	0	668.1	0	668.1	0	668.0

Project Name:
Dataset Name: Water Storage-Subtotal.trc

TRACE® 700 v6.2.7 calculated at 10:58 AM on 10/30/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

May	Typical Weather (℉)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	75.7	56.1	0	822.1	0	738.4	0	738.7	0	738.8	0	738.8
2	73.7	55.3	0	778.0	0	678.5	0	678.7	0	678.7	0	678.7
3	71.6	54.6	0	743.0	0	617.4	0	617.5	0	617.5	0	617.5
4	70.3	54.2	0	716.7	0	575.6	0	575.6	0	575.6	0	575.6
5	68.9	53.5	0	704.6	0	533.4	0	533.4	0	533.4	0	533.4
6	67.8	53.0	0	713.4	0	500.7	0	500.7	0	500.7	0	500.7
7	70.1	54.0	0	920.7	0	723.9	0	723.8	0	723.8	0	723.8
8	74.1	55.3	0	1,381.8	0	1,214.5	0	1,214.5	0	1,214.5	0	1,214.5
9	78.2	56.7	0	1,510.1	0	1,351.0	0	1,351.1	0	1,351.1	0	1,351.1
10	81.5	58.0	0	1,633.1	0	1,451.0	0	1,451.1	0	1,451.1	0	1,451.1
11	84.6	58.7	0	1,722.9	0	1,503.3	0	1,518.5	0	1,518.5	0	1,503.5
12	87.2	59.4	0	1,835.4	0	1,567.9	0	1,589.8	0	1,589.8	0	1,568.1
13	89.3	59.8	0	1,884.4	0	1,582.6	0	1,611.3	0	1,611.3	0	1,583.0
14	91.3	60.2	0	1,999.0	0	1,685.8	0	1,714.7	0	1,714.7	0	1,686.2
15	92.3	60.2	0	2,058.6	0	1,739.4	0	1,768.5	0	1,768.6	0	1,739.9
16	92.3	60.1	0	2,095.4	0	1,787.2	0	1,816.4	0	1,816.5	0	1,787.7
17	91.9	59.7	0	2,149.5	0	1,869.2	0	1,883.3	0	1,883.3	0	1,869.8
18	91.1	59.4	0	2,196.0	0	1,965.4	0	1,972.9	0	1,972.9	0	1,966.0
19	89.1	58.5	0	2,103.6	0	1,919.4	0	1,920.3	0	1,920.4	0	1,920.0
20	86.2	58.2	0	1,948.1	0	1,799.8	0	1,800.4	0	1,800.5	0	1,800.2
21	82.5	57.8	0	1,780.7	0	1,634.3	0	1,634.7	0	1,634.7	0	1,634.5
22	80.5	57.3	0	1,485.5	0	1,375.6	0	1,375.8	0	1,375.8	0	1,375.8
23	79.3	57.0	0	1,114.5	0	1,037.1	0	1,037.2	0	1,037.2	0	1,037.1
24	77.7	56.6	0	941.6	0	872.2	0	872.3	0	872.3	0	872.2

June	Typical Weather (℉)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	87.4	61.7	0	1,199.7	0	1,077.6	0	1,077.2	0	1,077.1	0	1,077.1
2	85.7	61.4	0	1,156.3	0	1,022.9	0	1,022.5	0	1,022.4	0	1,022.4
3	84.4	61.3	0	1,122.7	0	980.6	0	980.1	0	980.1	0	980.1
4	82.6	60.9	0	1,097.3	0	928.1	0	927.9	0	927.9	0	927.9
5	81.4	60.4	0	1,085.6	0	890.7	0	890.5	0	890.6	0	890.6
6	80.9	60.1	0	1,094.0	0	871.0	0	870.8	0	870.8	0	870.8
7	82.8	60.8	0	1,302.6	0	1,090.3	0	1,090.2	0	1,090.3	0	1,090.3
8	86.3	61.9	0	1,764.9	0	1,574.1	0	1,574.3	0	1,574.4	0	1,574.4
9	90.0	63.0	0	1,889.7	0	1,705.1	0	1,705.2	0	1,705.3	0	1,705.3
10	93.6	63.9	0	2,004.1	0	1,813.6	0	1,813.5	0	1,813.6	0	1,813.6
11	96.7	64.7	0	2,085.1	0	1,870.0	0	1,884.7	0	1,884.8	0	1,869.7
12	99.1	65.2	0	2,189.4	0	1,932.6	0	1,953.8	0	1,953.7	0	1,932.1
13	101.4	65.8	0	2,232.3	0	1,954.5	0	1,982.5	0	1,982.5	0	1,954.1
14	103.0	66.2	0	2,343.4	0	2,046.7	0	2,074.8	0	2,074.8	0	2,046.4
15	103.9	66.3	0	2,400.9	0	2,096.6	0	2,124.8	0	2,124.8	0	2,096.4
16	104.2	66.4	0	2,440.7	0	2,150.1	0	2,178.3	0	2,178.3	0	2,149.9
17	103.8	66.2	0	2,502.4	0	2,235.9	0	2,248.8	0	2,248.8	0	2,235.6
18	102.8	65.9	0	2,560.9	0	2,332.3	0	2,338.5	0	2,338.5	0	2,332.0
19	100.5	65.1	0	2,480.9	0	2,282.6	0	2,282.2	0	2,282.2	0	2,282.3
20	97.7	64.2	0	2,339.6	0	2,159.5	0	2,159.2	0	2,159.2	0	2,159.3
21	95.2	63.7	0	2,166.9	0	2,018.8	0	2,018.5	0	2,018.5	0	2,018.6
22	92.8	63.4	0	1,865.1	0	1,737.2	0	1,737.0	0	1,737.0	0	1,737.0
23	90.8	63.0	0	1,492.6	0	1,376.9	0	1,376.8	0	1,376.8	0	1,376.8
24	89.3	62.5	0	1,319.0	0	1,209.0	0	1,209.0	0	1,208.9	0	1,209.0

Project Name:
Dataset Name: Water Storage-Subtotal.trc

TRACE® 700 v6.2.7 calculated at 10:58 AM on 10/30/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

July	Typical Weather (℉)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	91.2	69.1	0	1,335.0	0	1,368.1	0	1,396.7	0	1,397.4	0	1,397.4
2	89.6	68.8	0	1,306.0	0	1,336.9	0	1,360.6	0	1,361.2	0	1,361.2
3	88.3	68.5	0	1,284.2	0	1,307.9	0	1,327.6	0	1,328.1	0	1,328.1
4	86.9	68.4	0	1,271.8	0	1,286.0	0	1,302.7	0	1,303.1	0	1,303.2
5	86.3	68.5	0	1,280.6	0	1,285.5	0	1,299.7	0	1,300.0	0	1,300.0
6	85.8	68.2	0	1,290.3	0	1,265.9	0	1,277.8	0	1,278.1	0	1,278.1
7	86.9	68.6	0	1,495.1	0	1,478.5	0	1,493.1	0	1,493.4	0	1,493.4
8	89.4	69.3	0	1,962.7	0	1,977.6	0	1,998.3	0	1,998.8	0	1,998.8
9	92.7	69.9	0	2,073.1	0	2,070.1	0	2,086.8	0	2,087.2	0	2,087.2
10	95.7	70.6	0	2,184.8	0	2,156.4	0	2,169.6	0	2,169.9	0	2,169.9
11	98.5	71.0	0	2,247.3	0	2,174.3	0	2,202.6	0	2,202.9	0	2,184.5
12	101.1	71.4	0	2,335.9	0	2,220.1	0	2,255.8	0	2,256.0	0	2,228.0
13	102.9	71.6	0	2,363.5	0	2,205.5	0	2,248.0	0	2,248.2	0	2,211.3
14	104.6	71.7	0	2,457.3	0	2,281.5	0	2,322.8	0	2,322.9	0	2,285.5
15	105.8	71.9	0	2,506.1	0	2,326.3	0	2,367.8	0	2,367.9	0	2,329.6
16	106.6	72.1	0	2,545.3	0	2,392.9	0	2,434.8	0	2,434.9	0	2,395.7
17	106.1	71.7	0	2,606.2	0	2,466.8	0	2,491.2	0	2,491.3	0	2,469.1
18	104.0	71.2	0	2,665.9	0	2,537.0	0	2,552.5	0	2,552.6	0	2,539.0
19	101.9	70.4	0	2,585.5	0	2,466.5	0	2,472.9	0	2,472.9	0	2,468.1
20	99.7	70.0	0	2,471.9	0	2,368.1	0	2,372.8	0	2,372.9	0	2,369.2
21	97.5	70.0	0	2,309.8	0	2,269.4	0	2,273.0	0	2,273.0	0	2,270.3
22	95.8	69.7	0	2,018.6	0	2,016.4	0	2,018.8	0	2,018.8	0	2,017.0
23	93.9	69.6	0	1,655.0	0	1,668.0	0	1,669.5	0	1,669.5	0	1,668.3
24	92.9	69.7	0	1,494.0	0	1,529.5	0	1,530.5	0	1,530.5	0	1,529.7

August	Typical Weather (℉)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	88.3	68.0	0	1,292.3	0	1,267.1	0	1,293.5	0	1,294.1	0	1,294.1
2	86.6	67.5	0	1,257.3	0	1,227.3	0	1,249.2	0	1,249.7	0	1,249.7
3	85.8	67.4	0	1,232.0	0	1,210.1	0	1,228.3	0	1,228.7	0	1,228.7
4	84.4	67.2	0	1,220.1	0	1,188.9	0	1,204.2	0	1,204.6	0	1,204.6
5	83.3	67.0	0	1,213.5	0	1,166.1	0	1,179.0	0	1,179.3	0	1,179.3
6	82.5	66.8	0	1,223.0	0	1,148.3	0	1,159.4	0	1,159.6	0	1,159.6
7	82.8	67.1	0	1,425.7	0	1,335.9	0	1,349.3	0	1,349.6	0	1,349.6
8	85.8	67.9	0	1,897.7	0	1,832.7	0	1,852.3	0	1,852.8	0	1,852.8
9	89.3	68.8	0	1,998.8	0	1,945.8	0	1,961.8	0	1,962.2	0	1,962.2
10	92.6	69.5	0	2,109.2	0	2,051.9	0	2,064.9	0	2,065.2	0	2,065.2
11	95.3	70.1	0	2,172.2	0	2,087.8	0	2,116.1	0	2,116.3	0	2,098.0
12	97.6	70.4	0	2,254.7	0	2,138.4	0	2,174.1	0	2,174.3	0	2,146.3
13	99.4	70.6	0	2,274.2	0	2,124.6	0	2,167.2	0	2,167.3	0	2,130.5
14	100.9	70.9	0	2,371.3	0	2,212.5	0	2,255.5	0	2,255.6	0	2,217.3
15	101.7	71.0	0	2,419.7	0	2,250.1	0	2,291.5	0	2,291.6	0	2,253.3
16	102.3	70.8	0	2,450.1	0	2,295.4	0	2,337.2	0	2,337.2	0	2,298.0
17	102.5	70.8	0	2,507.1	0	2,388.5	0	2,412.8	0	2,412.9	0	2,390.7
18	102.0	70.5	0	2,553.6	0	2,481.7	0	2,497.1	0	2,497.1	0	2,483.7
19	100.1	69.8	0	2,454.6	0	2,410.5	0	2,416.7	0	2,416.7	0	2,412.0
20	97.6	69.3	0	2,310.6	0	2,294.2	0	2,298.8	0	2,298.8	0	2,295.3
21	95.1	68.9	0	2,165.3	0	2,172.0	0	2,175.5	0	2,175.5	0	2,172.9
22	92.6	68.5	0	1,897.3	0	1,907.5	0	1,909.8	0	1,909.8	0	1,908.0
23	91.1	68.1	0	1,531.6	0	1,543.3	0	1,544.8	0	1,544.8	0	1,543.7
24	89.5	67.9	0	1,370.9	0	1,384.1	0	1,385.1	0	1,385.1	0	1,384.3

Project Name:
Dataset Name: Water Storage-Subtotal.trc

TRACE® 700 v6.2.7 calculated at 10:58 AM on 10/30/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

September	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	81.6	62.1	0	1,039.8	0	900.8	0	909.5	0	910.9	0	911.0
2	80.5	61.6	0	1,002.1	0	864.1	0	871.3	0	872.5	0	872.5
3	79.2	61.2	0	972.1	0	825.1	0	835.4	0	836.4	0	836.4
4	78.0	60.9	0	949.5	0	790.0	0	802.1	0	803.0	0	803.0
5	76.8	60.7	0	939.1	0	757.9	0	770.7	0	771.5	0	771.5
6	76.3	60.7	0	947.2	0	748.7	0	759.9	0	760.6	0	760.6
7	76.5	60.7	0	1,116.5	0	893.4	0	908.1	0	909.0	0	909.0
8	79.2	61.4	0	1,553.1	0	1,342.2	0	1,366.2	0	1,367.6	0	1,367.7
9	83.0	62.8	0	1,669.3	0	1,475.1	0	1,496.6	0	1,497.9	0	1,497.9
10	86.5	63.9	0	1,819.2	0	1,624.2	0	1,643.6	0	1,644.8	0	1,644.8
11	89.8	64.9	0	1,919.5	0	1,705.3	0	1,737.9	0	1,738.9	0	1,722.6
12	92.5	65.4	0	2,029.0	0	1,780.3	0	1,818.4	0	1,819.2	0	1,794.8
13	94.9	65.6	0	2,070.8	0	1,800.6	0	1,843.6	0	1,844.3	0	1,812.2
14	96.6	66.0	0	2,179.2	0	1,899.4	0	1,940.5	0	1,941.1	0	1,908.0
15	97.7	66.1	0	2,235.8	0	1,961.4	0	1,996.4	0	1,996.9	0	1,963.0
16	97.6	66.0	0	2,270.1	0	2,006.6	0	2,037.6	0	2,038.0	0	2,006.9
17	96.5	65.5	0	2,313.5	0	2,057.2	0	2,071.0	0	2,071.0	0	2,057.5
18	95.2	65.3	0	2,332.8	0	2,108.5	0	2,115.6	0	2,115.6	0	2,108.8
19	92.3	64.1	0	2,206.4	0	1,992.6	0	1,993.0	0	1,993.0	0	1,992.8
20	89.8	64.0	0	2,054.0	0	1,868.8	0	1,870.6	0	1,870.9	0	1,869.0
21	87.3	63.7	0	1,916.5	0	1,748.5	0	1,756.4	0	1,756.6	0	1,753.3
22	86.0	63.5	0	1,665.6	0	1,532.0	0	1,537.6	0	1,537.7	0	1,535.4
23	84.3	63.0	0	1,311.1	0	1,184.1	0	1,187.2	0	1,187.3	0	1,186.0
24	82.6	62.6	0	1,149.7	0	1,020.3	0	1,022.3	0	1,022.4	0	1,021.5

October	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	71.6	56.7	0	750.5	0	610.0	0	609.8	0	609.9	0	609.9
2	70.1	56.0	0	712.7	0	565.5	0	565.2	0	565.2	0	565.2
3	68.8	55.6	0	682.4	0	527.0	0	527.0	0	527.0	0	527.0
4	67.5	55.0	0	659.2	0	488.4	0	488.3	0	488.3	0	488.3
5	66.7	54.5	0	648.9	0	462.9	0	462.7	0	462.7	0	462.7
6	66.2	54.1	0	657.5	0	444.8	0	444.4	0	444.4	0	444.4
7	65.9	53.9	0	826.9	0	575.8	0	575.5	0	575.5	0	575.5
8	69.0	55.2	0	1,257.7	0	1,024.0	0	1,024.3	0	1,024.4	0	1,024.4
9	73.3	57.0	0	1,376.8	0	1,159.5	0	1,160.0	0	1,160.1	0	1,160.1
10	77.2	58.4	0	1,532.0	0	1,310.2	0	1,310.7	0	1,310.8	0	1,310.8
11	81.0	59.6	0	1,641.7	0	1,405.5	0	1,421.0	0	1,421.1	0	1,406.1
12	83.9	60.6	0	1,754.9	0	1,492.1	0	1,514.2	0	1,514.3	0	1,492.7
13	86.1	61.5	0	1,800.2	0	1,519.8	0	1,548.5	0	1,548.6	0	1,520.3
14	87.8	61.6	0	1,913.0	0	1,620.2	0	1,648.8	0	1,648.8	0	1,620.4
15	88.4	61.8	0	1,970.7	0	1,667.1	0	1,695.6	0	1,695.6	0	1,667.2
16	87.6	61.7	0	1,998.7	0	1,684.6	0	1,713.4	0	1,713.5	0	1,685.0
17	86.3	61.1	0	2,026.2	0	1,714.2	0	1,727.8	0	1,727.8	0	1,714.4
18	83.5	60.2	0	2,005.9	0	1,698.0	0	1,705.1	0	1,705.2	0	1,698.4
19	80.9	59.7	0	1,868.0	0	1,591.6	0	1,592.0	0	1,592.1	0	1,591.9
20	78.6	59.2	0	1,722.0	0	1,485.1	0	1,485.4	0	1,485.4	0	1,485.3
21	76.9	58.4	0	1,615.6	0	1,410.8	0	1,411.1	0	1,411.2	0	1,411.0
22	75.3	57.9	0	1,370.5	0	1,194.7	0	1,194.9	0	1,195.0	0	1,194.9
23	74.2	57.5	0	1,020.4	0	870.1	0	870.2	0	870.2	0	870.2
24	72.9	56.9	0	861.1	0	717.8	0	717.9	0	717.9	0	717.8

Project Name:
Dataset Name: Water Storage-Subtotal.trc

TRACE® 700 v6.2.7 calculated at 10:58 AM on 10/30/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

November	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	59.7	48.4	0	406.5	0	263.9	0	264.2	0	264.2	0	264.2
2	58.4	47.7	0	371.9	0	227.0	0	227.2	0	227.2	0	227.2
3	57.4	47.3	0	344.3	0	196.4	0	196.6	0	196.6	0	196.6
4	56.3	46.7	0	322.8	0	165.4	0	165.6	0	165.6	0	165.6
5	55.7	46.3	0	313.3	0	145.4	0	145.6	0	145.6	0	145.6
6	54.9	46.2	0	321.2	0	123.0	0	123.1	0	123.1	0	123.1
7	54.6	45.9	0	488.0	0	251.5	0	251.6	0	251.6	0	251.6
8	56.1	46.8	0	889.1	0	636.3	0	636.4	0	636.4	0	636.4
9	60.3	48.7	0	989.3	0	762.1	0	762.2	0	762.2	0	762.2
10	64.5	50.6	0	1,131.1	0	919.1	0	919.3	0	919.3	0	919.3
11	68.1	51.8	0	1,252.0	0	1,027.3	0	1,042.3	0	1,042.4	0	1,027.5
12	70.9	52.9	0	1,362.1	0	1,113.8	0	1,135.5	0	1,135.5	0	1,114.0
13	73.1	53.7	0	1,402.3	0	1,137.8	0	1,166.1	0	1,166.1	0	1,138.0
14	74.3	54.2	0	1,508.5	0	1,225.8	0	1,254.2	0	1,254.2	0	1,226.0
15	75.5	54.6	0	1,559.4	0	1,284.4	0	1,313.0	0	1,313.0	0	1,284.7
16	75.3	54.3	0	1,581.2	0	1,314.0	0	1,342.6	0	1,342.6	0	1,314.2
17	74.0	53.7	0	1,596.0	0	1,336.5	0	1,350.1	0	1,350.1	0	1,336.8
18	70.7	52.5	0	1,575.0	0	1,305.9	0	1,312.8	0	1,312.9	0	1,306.2
19	68.4	51.7	0	1,449.2	0	1,208.6	0	1,208.9	0	1,208.9	0	1,208.8
20	65.9	50.8	0	1,327.7	0	1,105.3	0	1,105.5	0	1,105.5	0	1,105.4
21	64.3	50.3	0	1,236.9	0	1,041.3	0	1,041.4	0	1,041.4	0	1,041.4
22	63.0	49.9	0	1,003.6	0	835.1	0	835.2	0	835.2	0	835.2
23	61.7	49.1	0	662.4	0	509.4	0	509.4	0	509.5	0	509.4
24	60.4	48.6	0	508.9	0	359.6	0	359.6	0	359.6	0	359.6

December	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	49.2	42.1	0	101.3	-454,378	0.0	-454,479	0.0	-454,479	0.0	-454,479	0.0
2	48.2	41.7	0	70.9	-835,758	0.0	-835,713	0.0	-835,713	0.0	-835,713	0.0
3	47.5	41.4	0	46.1	-1,075,904	0.0	-1,075,904	0.0	-1,075,904	0.0	-1,075,904	0.0
4	46.5	40.9	0	27.6	-1,430,865	0.0	-1,430,865	0.0	-1,430,865	0.0	-1,430,865	0.0
5	45.7	40.5	0	19.2	-1,718,419	0.0	-1,718,419	0.0	-1,718,419	0.0	-1,718,419	0.0
6	45.3	40.3	0	26.1	-1,873,115	0.0	-1,873,115	0.0	-1,873,115	0.0	-1,873,115	0.0
7	44.8	39.9	0	187.4	-389,466	0.0	-389,466	0.0	-389,466	0.0	-389,466	0.0
8	45.3	40.3	0	570.5	0	317.8	0	318.6	0	318.7	0	318.7
9	48.5	41.7	0	648.2	0	401.6	0	402.4	0	402.5	0	402.5
10	51.8	43.1	0	772.4	0	520.1	0	521.0	0	521.1	0	521.1
11	55.1	44.7	0	888.1	0	621.2	0	636.8	0	636.9	0	622.1
12	57.7	45.8	0	997.2	0	707.1	0	729.3	0	729.4	0	707.9
13	59.9	46.4	0	1,031.8	0	732.8	0	761.7	0	761.7	0	733.6
14	61.5	47.1	0	1,128.6	0	827.6	0	856.7	0	856.8	0	828.5
15	62.6	47.3	0	1,174.7	0	880.1	0	909.4	0	909.5	0	881.0
16	63.0	47.5	0	1,198.9	0	927.8	0	957.2	0	957.3	0	928.6
17	61.9	47.2	0	1,222.3	0	967.5	0	981.9	0	982.0	0	968.3
18	59.5	46.7	0	1,212.1	0	969.2	0	976.8	0	976.8	0	969.8
19	57.2	46.4	0	1,097.4	0	875.6	0	876.3	0	876.4	0	876.0
20	55.0	45.4	0	986.2	0	781.6	0	782.2	0	782.2	0	781.9
21	54.0	44.9	0	904.3	0	732.9	0	733.4	0	733.5	0	733.2
22	52.5	44.0	0	680.3	0	524.2	0	524.6	0	524.6	0	524.4
23	51.2	43.1	0	348.9	0	203.5	0	203.7	0	203.7	0	203.6
24	50.0	42.7	0	202.2	0	57.1	0	57.2	0	57.2	0	57.2

Project Name:
Dataset Name: Water Storage-Subtotal.trc

TRACE® 700 v6.2.7 calculated at 10:58 AM on 10/30/2012
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Appendix F. Building Load Profile - Phase 11 (Final), After New Surgery

BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	51.1	41.5	-193,392	0.0	-569,587	0.0	-569,713	0.0	-569,713	0.0	-569,713	0.0
2	50.3	41.0	-552,903	0.0	-939,089	0.0	-939,030	0.0	-939,030	0.0	-939,030	0.0
3	49.3	40.7	-842,236	0.0	-1,382,192	0.0	-1,382,192	0.0	-1,382,192	0.0	-1,382,192	0.0
4	48.4	39.9	-1,057,912	0.0	-1,791,411	0.0	-1,791,411	0.0	-1,791,411	0.0	-1,791,411	0.0
5	47.5	39.5	-1,126,188	0.0	-2,197,030	0.0	-2,197,030	0.0	-2,197,030	0.0	-2,197,030	0.0
6	46.9	39.2	-980,314	0.0	-2,458,840	0.0	-2,458,840	0.0	-2,458,840	0.0	-2,458,840	0.0
7	46.7	38.9	-614,880	0.0	-702,827	0.0	-702,827	0.0	-702,827	0.0	-702,827	0.0
8	46.7	39.0	0	0.0	0	318.5	0	318.5	0	318.5	0	318.5
9	49.8	40.5	0	184.9	0	417.3	0	417.3	0	417.3	0	417.3
10	53.7	42.5	0	923.0	0	583.2	0	583.3	0	583.3	0	583.3
11	57.3	43.8	0	1,085.7	0	719.1	0	735.8	0	735.8	0	719.2
12	60.1	45.2	0	1,235.1	0	838.6	0	862.7	0	862.8	0	838.7
13	62.0	46.0	0	1,289.8	0	872.9	0	904.4	0	904.5	0	873.0
14	64.2	47.2	0	1,410.1	0	1,008.6	0	1,040.4	0	1,040.4	0	1,008.7
15	65.7	47.7	0	1,472.6	0	1,098.8	0	1,130.7	0	1,130.7	0	1,098.9
16	65.9	47.7	0	1,514.2	0	1,159.1	0	1,191.0	0	1,191.1	0	1,159.1
17	65.6	47.8	0	1,560.2	0	1,251.5	0	1,266.5	0	1,266.5	0	1,251.5
18	62.7	46.9	0	1,538.0	0	1,227.8	0	1,235.4	0	1,235.4	0	1,227.9
19	60.6	45.9	0	1,376.1	0	1,111.6	0	1,111.7	0	1,111.7	0	1,111.6
20	58.2	45.1	0	1,204.3	0	961.9	0	962.0	0	962.0	0	961.9
21	56.4	44.4	0	1,085.2	0	870.7	0	870.8	0	870.8	0	870.7
22	54.8	43.5	0	812.9	0	621.0	0	621.0	0	621.0	0	621.0
23	53.5	42.8	0	423.1	0	248.8	0	248.8	0	248.8	0	248.8
24	52.5	42.2	0	247.1	0	83.3	0	83.3	0	83.3	0	83.3

February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	55.7	48.1	0	292.5	0	122.4	0	122.2	0	122.2	0	122.2
2	54.4	47.9	0	250.4	0	74.5	0	74.2	0	74.2	0	74.2
3	53.5	47.4	0	216.1	0	38.2	0	38.0	0	37.9	0	37.9
4	52.7	47.1	0	190.4	0	0.0	0	0.0	0	0.0	0	0.0
5	51.9	46.6	0	178.7	-314,043	0.0	-314,043	0.0	-314,043	0.0	-314,043	0.0
6	51.4	46.3	0	187.6	-571,120	0.0	-571,120	0.0	-571,120	0.0	-571,120	0.0
7	50.9	45.9	0	376.2	0	94.5	0	94.2	0	94.1	0	94.1
8	52.0	46.3	0	831.9	0	518.0	0	517.4	0	517.4	0	517.4
9	55.0	47.6	0	956.9	0	633.6	0	633.1	0	633.0	0	633.0
10	58.4	49.1	0	1,135.9	0	797.7	0	797.3	0	797.3	0	797.2
11	62.1	50.5	0	1,295.8	0	940.5	0	957.0	0	957.0	0	940.2
12	65.2	51.5	0	1,438.7	0	1,059.3	0	1,083.3	0	1,083.2	0	1,059.0
13	67.4	52.4	0	1,491.9	0	1,096.2	0	1,127.8	0	1,127.8	0	1,096.1
14	69.2	52.6	0	1,613.0	0	1,211.6	0	1,243.4	0	1,243.4	0	1,211.5
15	70.0	52.7	0	1,679.6	0	1,270.8	0	1,302.9	0	1,302.8	0	1,270.8
16	70.5	52.6	0	1,729.0	0	1,341.2	0	1,373.4	0	1,373.4	0	1,341.2
17	70.0	52.3	0	1,790.9	0	1,429.6	0	1,444.7	0	1,444.7	0	1,429.7
18	68.1	51.5	0	1,810.0	0	1,476.3	0	1,483.8	0	1,483.8	0	1,476.3
19	65.3	50.9	0	1,647.7	0	1,344.8	0	1,344.8	0	1,344.8	0	1,344.8
20	63.4	50.5	0	1,455.5	0	1,209.5	0	1,209.4	0	1,209.4	0	1,209.4
21	61.6	50.4	0	1,288.2	0	1,079.7	0	1,079.5	0	1,079.5	0	1,079.6
22	60.0	49.9	0	1,001.9	0	821.6	0	821.5	0	821.5	0	821.6
23	58.7	49.4	0	600.8	0	441.9	0	441.8	0	441.8	0	441.8
24	57.5	49.0	0	418.6	0	267.7	0	267.6	0	267.6	0	267.6

Project Name:
Dataset Name: Water Storage-Future.trc

TRACE® 700 v6.2.7 calculated at 11:00 AM on 10/30/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

March	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	59.1	48.6	0	390.4	0	243.8	0	244.0	0	244.0	0	244.0
2	57.7	48.0	0	348.4	0	192.1	0	192.2	0	192.2	0	192.2
3	56.2	47.4	0	315.3	0	137.2	0	137.2	0	137.2	0	137.2
4	55.1	46.8	0	290.0	0	96.7	0	96.8	0	96.8	0	96.8
5	54.3	46.4	0	278.6	0	63.0	0	63.0	0	63.0	0	63.0
6	53.8	46.0	0	286.7	0	44.2	0	44.2	0	44.2	0	44.2
7	53.7	45.7	0	474.1	0	193.8	0	193.9	0	194.0	0	194.0
8	56.0	46.8	0	962.7	0	684.6	0	684.9	0	684.9	0	684.9
9	59.8	48.5	0	1,097.2	0	832.9	0	833.2	0	833.2	0	833.2
10	62.9	49.6	0	1,273.9	0	992.9	0	993.2	0	993.2	0	993.3
11	65.5	50.7	0	1,395.6	0	1,074.0	0	1,091.2	0	1,091.2	0	1,074.3
12	67.8	51.4	0	1,522.2	0	1,163.0	0	1,187.8	0	1,187.9	0	1,163.4
13	69.4	51.9	0	1,567.1	0	1,171.5	0	1,203.9	0	1,204.0	0	1,171.9
14	70.8	52.3	0	1,686.5	0	1,273.4	0	1,306.1	0	1,306.1	0	1,273.8
15	71.5	52.6	0	1,754.1	0	1,329.2	0	1,362.0	0	1,362.0	0	1,329.6
16	72.3	52.8	0	1,806.5	0	1,414.8	0	1,447.7	0	1,447.8	0	1,415.2
17	72.1	52.7	0	1,872.7	0	1,515.3	0	1,531.0	0	1,531.0	0	1,515.7
18	71.2	52.6	0	1,911.1	0	1,611.1	0	1,619.2	0	1,619.2	0	1,611.5
19	69.4	52.1	0	1,758.7	0	1,510.1	0	1,510.5	0	1,510.5	0	1,510.3
20	67.2	51.5	0	1,568.6	0	1,368.3	0	1,368.6	0	1,368.7	0	1,368.5
21	65.3	50.7	0	1,388.3	0	1,222.4	0	1,222.7	0	1,222.7	0	1,222.6
22	63.4	50.0	0	1,099.0	0	951.3	0	951.4	0	951.4	0	951.4
23	62.0	49.8	0	695.9	0	565.9	0	565.9	0	565.9	0	565.9
24	60.5	49.3	0	513.4	0	379.2	0	379.3	0	379.3	0	379.3

April	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	68.5	50.2	0	680.0	0	582.9	0	583.1	0	583.1	0	583.1
2	66.5	49.5	0	622.2	0	509.7	0	509.8	0	509.8	0	509.8
3	64.4	48.5	0	576.4	0	433.5	0	433.5	0	433.6	0	433.6
4	62.8	47.8	0	541.7	0	373.1	0	373.1	0	373.1	0	373.1
5	61.6	47.4	0	525.7	0	325.4	0	325.5	0	325.5	0	325.5
6	60.5	46.8	0	537.3	0	283.3	0	283.3	0	283.3	0	283.3
7	61.5	47.4	0	760.6	0	488.8	0	488.8	0	488.9	0	488.9
8	66.4	49.6	0	1,287.8	0	1,076.8	0	1,078.3	0	1,078.5	0	1,078.5
9	71.3	51.5	0	1,457.1	0	1,273.1	0	1,274.3	0	1,274.6	0	1,274.6
10	75.6	53.3	0	1,644.7	0	1,453.0	0	1,454.4	0	1,454.6	0	1,454.7
11	78.7	54.4	0	1,788.1	0	1,539.1	0	1,557.0	0	1,557.2	0	1,540.2
12	81.2	55.1	0	1,949.1	0	1,630.4	0	1,655.2	0	1,655.4	0	1,630.7
13	83.5	55.6	0	2,027.7	0	1,661.5	0	1,693.8	0	1,693.8	0	1,661.7
14	85.1	56.0	0	2,174.9	0	1,771.4	0	1,803.8	0	1,803.9	0	1,771.6
15	86.5	56.2	0	2,256.6	0	1,848.9	0	1,881.4	0	1,881.5	0	1,849.1
16	87.1	56.4	0	2,304.7	0	1,922.5	0	1,955.0	0	1,955.1	0	1,922.7
17	86.3	56.0	0	2,357.1	0	2,002.8	0	2,018.2	0	2,018.2	0	2,003.0
18	85.1	55.4	0	2,382.2	0	2,084.4	0	2,092.3	0	2,092.3	0	2,084.6
19	82.6	54.4	0	2,226.4	0	1,984.3	0	1,984.7	0	1,984.7	0	1,984.5
20	80.1	53.8	0	2,012.0	0	1,838.7	0	1,839.0	0	1,839.0	0	1,838.8
21	77.0	53.0	0	1,795.9	0	1,657.4	0	1,657.6	0	1,657.6	0	1,657.5
22	74.4	52.1	0	1,457.9	0	1,351.5	0	1,351.6	0	1,351.6	0	1,351.6
23	72.4	51.6	0	1,025.9	0	941.9	0	941.9	0	941.9	0	941.9
24	70.8	51.1	0	821.4	0	749.6	0	749.6	0	749.6	0	749.6

Project Name:
Dataset Name: Water Storage-Future.trc

TRACE® 700 v6.2.7 calculated at 11:00 AM on 10/30/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

May	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	75.7	56.1	0	946.3	0	842.5	0	842.9	0	842.9	0	842.9
2	73.7	55.3	0	891.1	0	768.3	0	768.5	0	768.5	0	768.5
3	71.6	54.6	0	847.4	0	692.7	0	692.8	0	692.8	0	692.8
4	70.3	54.2	0	814.6	0	640.8	0	640.8	0	640.8	0	640.8
5	68.9	53.5	0	799.3	0	588.5	0	588.5	0	588.5	0	588.5
6	67.8	53.0	0	809.8	0	548.0	0	548.0	0	548.0	0	548.0
7	70.1	54.0	0	1,052.9	0	810.1	0	810.1	0	810.1	0	810.1
8	74.1	55.3	0	1,591.4	0	1,383.6	0	1,383.7	0	1,383.7	0	1,383.7
9	78.2	56.7	0	1,757.6	0	1,559.0	0	1,559.1	0	1,559.1	0	1,559.1
10	81.5	58.0	0	1,915.6	0	1,687.9	0	1,688.0	0	1,688.0	0	1,688.0
11	84.6	58.7	0	2,034.2	0	1,759.6	0	1,776.9	0	1,777.0	0	1,759.9
12	87.2	59.4	0	2,175.9	0	1,841.7	0	1,866.7	0	1,866.8	0	1,842.1
13	89.3	59.8	0	2,242.1	0	1,864.9	0	1,897.6	0	1,897.7	0	1,865.3
14	91.3	60.2	0	2,382.7	0	1,990.3	0	2,023.4	0	2,023.4	0	1,990.8
15	92.3	60.2	0	2,460.7	0	2,059.6	0	2,092.9	0	2,093.0	0	2,060.2
16	92.3	60.1	0	2,510.1	0	2,120.7	0	2,154.2	0	2,154.2	0	2,121.4
17	91.9	59.7	0	2,573.5	0	2,216.6	0	2,232.8	0	2,232.8	0	2,217.2
18	91.1	59.4	0	2,619.4	0	2,322.9	0	2,331.6	0	2,331.6	0	2,323.6
19	89.1	58.5	0	2,497.9	0	2,259.3	0	2,260.4	0	2,260.4	0	2,260.0
20	86.2	58.2	0	2,296.5	0	2,104.5	0	2,105.2	0	2,105.3	0	2,104.9
21	82.5	57.8	0	2,081.2	0	1,895.3	0	1,895.7	0	1,895.8	0	1,895.6
22	80.5	57.3	0	1,726.3	0	1,587.6	0	1,587.8	0	1,587.8	0	1,587.7
23	79.3	57.0	0	1,292.7	0	1,195.3	0	1,195.4	0	1,195.4	0	1,195.4
24	77.7	56.6	0	1,088.0	0	1,001.4	0	1,001.4	0	1,001.4	0	1,001.4

June	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	87.4	61.7	0	1,412.7	0	1,261.8	0	1,261.3	0	1,261.3	0	1,261.3
2	85.7	61.4	0	1,358.4	0	1,193.7	0	1,193.2	0	1,193.2	0	1,193.2
3	84.4	61.3	0	1,316.3	0	1,141.0	0	1,140.6	0	1,140.5	0	1,140.5
4	82.6	60.9	0	1,284.6	0	1,076.1	0	1,075.8	0	1,075.8	0	1,075.8
5	81.4	60.4	0	1,269.8	0	1,029.7	0	1,029.5	0	1,029.5	0	1,029.5
6	80.9	60.1	0	1,279.8	0	1,005.1	0	1,004.8	0	1,004.8	0	1,004.8
7	82.8	60.8	0	1,525.0	0	1,262.9	0	1,262.7	0	1,262.7	0	1,262.8
8	86.3	61.9	0	2,065.4	0	1,828.9	0	1,829.0	0	1,829.1	0	1,829.1
9	90.0	63.0	0	2,227.5	0	1,997.8	0	1,997.8	0	1,997.9	0	1,997.9
10	93.6	63.9	0	2,375.1	0	2,137.6	0	2,137.3	0	2,137.4	0	2,137.4
11	96.7	64.7	0	2,483.2	0	2,215.2	0	2,231.8	0	2,231.8	0	2,214.7
12	99.1	65.2	0	2,615.0	0	2,295.7	0	2,320.0	0	2,319.9	0	2,295.3
13	101.4	65.8	0	2,673.9	0	2,328.1	0	2,360.1	0	2,360.1	0	2,327.7
14	103.0	66.2	0	2,810.1	0	2,440.2	0	2,472.4	0	2,472.4	0	2,439.9
15	103.9	66.3	0	2,885.3	0	2,504.9	0	2,537.1	0	2,537.1	0	2,504.6
16	104.2	66.4	0	2,938.0	0	2,572.9	0	2,605.2	0	2,605.1	0	2,572.7
17	103.8	66.2	0	3,010.3	0	2,673.5	0	2,688.4	0	2,688.3	0	2,673.3
18	102.8	65.9	0	3,071.2	0	2,780.1	0	2,787.4	0	2,787.3	0	2,779.9
19	100.5	65.1	0	2,970.8	0	2,712.2	0	2,711.9	0	2,711.9	0	2,712.0
20	97.7	64.2	0	2,777.1	0	2,552.5	0	2,552.3	0	2,552.3	0	2,552.4
21	95.2	63.7	0	2,560.6	0	2,373.0	0	2,372.7	0	2,372.7	0	2,372.8
22	92.8	63.4	0	2,196.9	0	2,036.1	0	2,035.9	0	2,035.9	0	2,036.0
23	90.8	63.0	0	1,760.7	0	1,616.4	0	1,616.3	0	1,616.3	0	1,616.3
24	89.3	62.5	0	1,554.7	0	1,418.2	0	1,418.2	0	1,418.2	0	1,418.2

Project Name:
Dataset Name: Water Storage-Future.trc

TRACE® 700 v6.2.7 calculated at 11:00 AM on 10/30/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

July	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	91.2	69.1	0	1,581.3	0	1,616.1	0	1,647.7	0	1,648.4	0	1,648.4
2	89.6	68.8	0	1,544.1	0	1,576.1	0	1,602.0	0	1,602.6	0	1,602.6
3	88.3	68.5	0	1,516.2	0	1,539.1	0	1,560.4	0	1,560.9	0	1,560.9
4	86.9	68.4	0	1,499.8	0	1,511.0	0	1,529.2	0	1,529.6	0	1,529.6
5	86.3	68.5	0	1,511.1	0	1,509.3	0	1,524.4	0	1,524.7	0	1,524.7
6	85.8	68.2	0	1,521.7	0	1,484.2	0	1,496.7	0	1,497.0	0	1,497.0
7	86.9	68.6	0	1,760.9	0	1,731.1	0	1,747.4	0	1,747.7	0	1,747.7
8	89.4	69.3	0	2,306.4	0	2,312.6	0	2,335.6	0	2,336.1	0	2,336.1
9	92.7	69.9	0	2,450.1	0	2,434.4	0	2,453.1	0	2,453.5	0	2,453.5
10	95.7	70.6	0	2,594.3	0	2,547.4	0	2,562.2	0	2,562.5	0	2,562.5
11	98.5	71.0	0	2,679.2	0	2,578.3	0	2,610.3	0	2,610.6	0	2,589.6
12	101.1	71.4	0	2,791.8	0	2,638.2	0	2,678.7	0	2,678.9	0	2,647.0
13	102.9	71.6	0	2,831.7	0	2,626.0	0	2,674.3	0	2,674.5	0	2,632.5
14	104.6	71.7	0	2,946.3	0	2,717.3	0	2,764.1	0	2,764.2	0	2,721.7
15	105.8	71.9	0	3,010.6	0	2,775.9	0	2,823.0	0	2,823.1	0	2,779.5
16	106.6	72.1	0	3,062.5	0	2,860.4	0	2,907.9	0	2,908.0	0	2,863.3
17	106.1	71.7	0	3,133.6	0	2,946.2	0	2,973.8	0	2,973.9	0	2,948.7
18	104.0	71.2	0	3,195.0	0	3,019.7	0	3,037.0	0	3,037.0	0	3,021.8
19	101.9	70.4	0	3,094.5	0	2,925.5	0	2,932.4	0	2,932.4	0	2,927.1
20	99.7	70.0	0	2,934.7	0	2,796.0	0	2,801.1	0	2,801.1	0	2,797.2
21	97.5	70.0	0	2,731.2	0	2,668.7	0	2,672.5	0	2,672.5	0	2,669.6
22	95.8	69.7	0	2,381.2	0	2,368.9	0	2,371.5	0	2,371.6	0	2,369.5
23	93.9	69.6	0	1,957.2	0	1,967.0	0	1,968.5	0	1,968.5	0	1,967.3
24	92.9	69.7	0	1,766.9	0	1,805.5	0	1,806.5	0	1,806.5	0	1,805.7

August	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	88.3	68.0	0	1,519.8	0	1,490.9	0	1,520.0	0	1,520.6	0	1,520.7
2	86.6	67.5	0	1,475.7	0	1,440.4	0	1,464.3	0	1,464.8	0	1,464.8
3	85.8	67.4	0	1,443.9	0	1,417.7	0	1,437.5	0	1,437.9	0	1,437.9
4	84.4	67.2	0	1,428.8	0	1,390.5	0	1,407.0	0	1,407.4	0	1,407.4
5	83.3	67.0	0	1,420.1	0	1,361.4	0	1,375.4	0	1,375.7	0	1,375.7
6	82.5	66.8	0	1,431.4	0	1,338.8	0	1,350.4	0	1,350.7	0	1,350.7
7	82.8	67.1	0	1,666.7	0	1,554.2	0	1,569.1	0	1,569.5	0	1,569.5
8	85.8	67.9	0	2,215.5	0	2,132.4	0	2,154.5	0	2,155.0	0	2,155.0
9	89.3	68.8	0	2,349.1	0	2,279.5	0	2,297.7	0	2,298.1	0	2,298.1
10	92.6	69.5	0	2,493.4	0	2,417.7	0	2,432.5	0	2,432.8	0	2,432.8
11	95.3	70.1	0	2,580.2	0	2,470.7	0	2,502.8	0	2,503.1	0	2,482.2
12	97.6	70.4	0	2,685.4	0	2,536.1	0	2,576.7	0	2,576.9	0	2,545.0
13	99.4	70.6	0	2,717.1	0	2,524.9	0	2,573.2	0	2,573.4	0	2,531.5
14	100.9	70.9	0	2,835.9	0	2,631.5	0	2,680.3	0	2,680.4	0	2,636.8
15	101.7	71.0	0	2,900.2	0	2,680.8	0	2,727.8	0	2,727.9	0	2,684.3
16	102.3	70.8	0	2,941.5	0	2,739.4	0	2,786.9	0	2,786.9	0	2,742.3
17	102.5	70.8	0	3,007.8	0	2,849.0	0	2,876.5	0	2,876.6	0	2,851.5
18	102.0	70.5	0	3,053.0	0	2,951.1	0	2,968.3	0	2,968.3	0	2,953.2
19	100.1	69.8	0	2,922.7	0	2,855.6	0	2,862.3	0	2,862.3	0	2,857.2
20	97.6	69.3	0	2,735.5	0	2,704.0	0	2,709.0	0	2,709.0	0	2,705.2
21	95.1	68.9	0	2,548.6	0	2,547.7	0	2,551.3	0	2,551.3	0	2,548.5
22	92.6	68.5	0	2,229.0	0	2,234.2	0	2,236.6	0	2,236.6	0	2,234.8
23	91.1	68.1	0	1,803.5	0	1,813.1	0	1,814.6	0	1,814.6	0	1,813.5
24	89.5	67.9	0	1,614.2	0	1,626.2	0	1,627.2	0	1,627.2	0	1,626.4

Project Name:
Dataset Name: Water Storage-Future.trc

TRACE® 700 v6.2.7 calculated at 11:00 AM on 10/30/2012
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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

September	Typical Weather (℉)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	81.6	62.1	0	1,214.2	0	1,042.5	0	1,050.7	0	1,052.1	0	1,052.1
2	80.5	61.6	0	1,167.1	0	996.8	0	1,003.0	0	1,004.2	0	1,004.2
3	79.2	61.2	0	1,129.8	0	948.4	0	958.4	0	959.4	0	959.4
4	78.0	60.9	0	1,101.7	0	904.9	0	917.0	0	917.8	0	917.9
5	76.8	60.7	0	1,088.6	0	865.0	0	878.0	0	878.7	0	878.7
6	76.3	60.7	0	1,098.2	0	853.0	0	864.2	0	864.8	0	864.8
7	76.5	60.7	0	1,292.6	0	1,016.1	0	1,031.5	0	1,032.3	0	1,032.3
8	79.2	61.4	0	1,799.9	0	1,536.3	0	1,562.5	0	1,563.9	0	1,564.0
9	83.0	62.8	0	1,950.2	0	1,706.2	0	1,729.8	0	1,731.1	0	1,731.2
10	86.5	63.9	0	2,142.4	0	1,896.3	0	1,917.9	0	1,919.1	0	1,919.1
11	89.8	64.9	0	2,273.5	0	2,003.6	0	2,040.2	0	2,041.2	0	2,022.7
12	92.5	65.4	0	2,411.2	0	2,098.4	0	2,141.2	0	2,142.1	0	2,114.3
13	94.9	65.6	0	2,468.2	0	2,128.7	0	2,177.2	0	2,177.9	0	2,141.3
14	96.6	66.0	0	2,601.2	0	2,252.7	0	2,295.4	0	2,296.0	0	2,258.4
15	97.7	66.1	0	2,676.3	0	2,333.3	0	2,368.6	0	2,369.1	0	2,333.7
16	97.6	66.0	0	2,722.5	0	2,392.3	0	2,425.5	0	2,425.5	0	2,392.7
17	96.5	65.5	0	2,772.0	0	2,450.1	0	2,465.8	0	2,465.9	0	2,450.4
18	95.2	65.3	0	2,783.1	0	2,500.4	0	2,508.5	0	2,508.5	0	2,500.7
19	92.3	64.1	0	2,617.5	0	2,348.5	0	2,349.0	0	2,349.0	0	2,348.8
20	89.8	64.0	0	2,420.0	0	2,187.7	0	2,188.0	0	2,188.0	0	2,187.9
21	87.3	63.7	0	2,244.4	0	2,029.3	0	2,037.8	0	2,038.0	0	2,034.2
22	86.0	63.5	0	1,946.9	0	1,775.7	0	1,781.6	0	1,781.8	0	1,779.2
23	84.3	63.0	0	1,534.4	0	1,373.3	0	1,376.5	0	1,376.6	0	1,375.2
24	82.6	62.6	0	1,344.4	0	1,181.1	0	1,183.2	0	1,183.2	0	1,182.3

October	Typical Weather (℉)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	71.6	56.7	0	857.1	0	683.1	0	682.8	0	682.9	0	682.9
2	70.1	56.0	0	810.1	0	628.1	0	627.7	0	627.7	0	627.7
3	68.8	55.6	0	772.4	0	580.5	0	580.4	0	580.5	0	580.5
4	67.5	55.0	0	743.5	0	532.8	0	532.6	0	532.6	0	532.6
5	66.7	54.5	0	730.6	0	501.2	0	500.9	0	500.9	0	500.9
6	66.2	54.1	0	740.7	0	478.7	0	478.4	0	478.3	0	478.3
7	65.9	53.9	0	935.2	0	625.8	0	625.3	0	625.3	0	625.3
8	69.0	55.2	0	1,434.3	0	1,145.6	0	1,145.7	0	1,145.8	0	1,145.8
9	73.3	57.0	0	1,587.2	0	1,317.7	0	1,318.2	0	1,318.3	0	1,318.3
10	77.2	58.4	0	1,784.8	0	1,508.8	0	1,509.4	0	1,509.4	0	1,509.4
11	81.0	59.6	0	1,927.3	0	1,633.0	0	1,650.4	0	1,650.5	0	1,633.5
12	83.9	60.6	0	2,068.9	0	1,741.6	0	1,766.6	0	1,766.6	0	1,742.1
13	86.1	61.5	0	2,130.0	0	1,780.7	0	1,813.4	0	1,813.4	0	1,781.2
14	87.8	61.6	0	2,268.5	0	1,903.5	0	1,935.8	0	1,935.8	0	1,903.5
15	88.4	61.8	0	2,344.4	0	1,965.2	0	1,997.4	0	1,997.4	0	1,965.0
16	87.6	61.7	0	2,382.5	0	1,989.4	0	2,022.0	0	2,022.0	0	1,989.5
17	86.3	61.1	0	2,411.5	0	2,020.2	0	2,035.4	0	2,035.4	0	2,020.1
18	83.5	60.2	0	2,371.5	0	1,985.8	0	1,993.5	0	1,993.5	0	1,985.8
19	80.9	59.7	0	2,191.9	0	1,845.9	0	1,846.4	0	1,846.4	0	1,846.2
20	78.6	59.2	0	2,003.7	0	1,707.9	0	1,708.3	0	1,708.3	0	1,708.2
21	76.9	58.4	0	1,869.3	0	1,614.1	0	1,614.4	0	1,614.4	0	1,614.3
22	75.3	57.9	0	1,580.1	0	1,361.4	0	1,361.6	0	1,361.6	0	1,361.5
23	74.2	57.5	0	1,174.0	0	987.3	0	987.4	0	987.5	0	987.4
24	72.9	56.9	0	987.2	0	809.6	0	809.6	0	809.7	0	809.6

Project Name:
Dataset Name: Water Storage-Future.trc

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BUILDING COOL HEAT DEMAND

By Westlake Reed Leskosky

November	Typical Weather (℉)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	59.7	48.4	0	431.6	0	255.8	0	256.1	0	256.1	0	256.1
2	58.4	47.7	0	388.6	0	210.1	0	210.4	0	210.4	0	210.4
3	57.4	47.3	0	354.3	0	172.4	0	172.6	0	172.6	0	172.6
4	56.3	46.7	0	327.6	0	134.2	0	134.3	0	134.3	0	134.3
5	55.7	46.3	0	315.7	0	109.4	0	109.6	0	109.6	0	109.6
6	54.9	46.2	0	325.2	0	81.8	0	81.9	0	81.9	0	81.9
7	54.6	45.9	0	516.1	0	225.3	0	225.4	0	225.4	0	225.4
8	56.1	46.8	0	976.6	0	665.0	0	665.2	0	665.3	0	665.3
9	60.3	48.7	0	1,105.0	0	824.4	0	824.6	0	824.7	0	824.7
10	64.5	50.6	0	1,284.8	0	1,022.5	0	1,022.7	0	1,022.7	0	1,022.7
11	68.1	51.8	0	1,441.4	0	1,163.0	0	1,180.1	0	1,180.2	0	1,163.3
12	70.9	52.9	0	1,578.9	0	1,271.4	0	1,296.1	0	1,296.1	0	1,271.7
13	73.1	53.7	0	1,633.4	0	1,305.7	0	1,338.0	0	1,338.1	0	1,306.1
14	74.3	54.2	0	1,763.3	0	1,412.6	0	1,445.0	0	1,445.0	0	1,412.9
15	75.5	54.6	0	1,830.2	0	1,488.2	0	1,520.8	0	1,520.8	0	1,488.5
16	75.3	54.3	0	1,860.0	0	1,526.8	0	1,559.5	0	1,559.5	0	1,527.1
17	74.0	53.7	0	1,872.5	0	1,548.7	0	1,564.2	0	1,564.2	0	1,549.0
18	70.7	52.5	0	1,831.9	0	1,496.9	0	1,504.8	0	1,504.8	0	1,497.1
19	68.4	51.7	0	1,668.5	0	1,369.4	0	1,369.7	0	1,369.7	0	1,369.6
20	65.9	50.8	0	1,512.4	0	1,236.5	0	1,236.8	0	1,236.8	0	1,236.7
21	64.3	50.3	0	1,398.4	0	1,155.9	0	1,156.1	0	1,156.1	0	1,156.0
22	63.0	49.9	0	1,124.7	0	915.9	0	916.0	0	916.0	0	916.0
23	61.7	49.1	0	730.6	0	541.3	0	541.4	0	541.4	0	541.4
24	60.4	48.6	0	551.6	0	367.0	0	367.1	0	367.1	0	367.1

December	Typical Weather (℉)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	49.2	42.1	0	56.0	-1,396,181	0.0	-1,396,249	0.0	-1,396,249	0.0	-1,396,249	0.0
2	48.2	41.7	0	18.3	-1,866,809	0.0	-1,866,809	0.0	-1,866,809	0.0	-1,866,809	0.0
3	47.5	41.4	-149,330	0.0	-2,163,593	0.0	-2,163,593	0.0	-2,163,593	0.0	-2,163,593	0.0
4	46.5	40.9	-427,265	0.0	-2,600,765	0.0	-2,600,765	0.0	-2,600,765	0.0	-2,600,765	0.0
5	45.7	40.5	-554,951	0.0	-2,955,053	0.0	-2,955,053	0.0	-2,955,053	0.0	-2,955,053	0.0
6	45.3	40.3	-454,620	0.0	-3,146,301	0.0	-3,146,301	0.0	-3,146,301	0.0	-3,146,301	0.0
7	44.8	39.9	0	146.4	-1,499,662	0.0	-1,499,662	0.0	-1,499,662	0.0	-1,499,662	0.0
8	45.3	40.3	0	582.3	0	271.6	0	272.5	0	272.6	0	272.6
9	48.5	41.7	0	682.5	0	378.8	0	379.7	0	379.7	0	379.8
10	51.8	43.1	0	840.9	0	528.7	0	529.6	0	529.7	0	529.7
11	55.1	44.7	0	991.4	0	660.2	0	677.9	0	678.0	0	661.2
12	57.7	45.8	0	1,127.9	0	767.7	0	792.9	0	793.0	0	768.7
13	59.9	46.4	0	1,175.2	0	803.9	0	836.6	0	836.7	0	804.8
14	61.5	47.1	0	1,292.7	0	918.3	0	951.4	0	951.5	0	919.3
15	62.6	47.3	0	1,353.2	0	985.7	0	1,019.0	0	1,019.1	0	986.6
16	63.0	47.5	0	1,385.7	0	1,046.3	0	1,079.7	0	1,079.8	0	1,047.2
17	61.9	47.2	0	1,409.4	0	1,089.8	0	1,106.2	0	1,106.3	0	1,090.6
18	59.5	46.7	0	1,382.7	0	1,078.6	0	1,087.1	0	1,087.2	0	1,079.2
19	57.2	46.4	0	1,233.6	0	956.5	0	957.2	0	957.3	0	956.9
20	55.0	45.4	0	1,090.7	0	835.6	0	836.2	0	836.2	0	835.9
21	54.0	44.9	0	987.8	0	774.1	0	774.6	0	774.6	0	774.3
22	52.5	44.0	0	725.9	0	531.4	0	531.8	0	531.8	0	531.6
23	51.2	43.1	0	344.3	0	163.7	0	163.9	0	163.9	0	163.8
24	50.0	42.7	0	173.7	-92,045	0.0	-92,045	0.0	-92,045	0.0	-92,045	0.0

Project Name:
Dataset Name: Water Storage-Future.trc

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Appendix G. Measurement and Verification Study Results of 7/13/2012

Update: Several items were identified AFTER the 7/13/2012 Experiment that CORRECTED the model.

1. ***Valve to old 8" main was found 90% closed. This explains why the model poorly predicted Bldg 1.***

2. ***Many control valve Cv-values and balancing valve settings were investigated and identified.***

3. ***Initially, the thought was that the Laundry flow sensor, 'CW9' was faulty. Instead, the laundry units were identified as being oversized and running at low setting. The 'CW9' sensor appears to be correct.***

The Central Plant was visited on 7/3/12 to observe the behavior of the pumps, chillers, and air handling units.

The pumps in the plant were ramped up to (4) different pressure setpoints, and the temperatures, flows, speeds, and energy use were recorded.

The minimum pressure setpoints (measured across the house pumps) were 10 PSI, 13.5 PSI, 20 PSI, and 29.5 PSI. Additionally, Chiller #4 was enabled at 29.5 PSI to observe the flow through the decoupler loop. The results are summarized in Table 13.

CHILLED WATER RESULTS SUMMARY										
DESCRIPTION	10.0 PSI		13.5 PSI		20.0 PSI		29.5 PSI		29.5 PSI w/ CH-4	
O/A Conditions °F / %Rh	87.7	43.8	88.8	43.1	89	42.6	90.5	42.6	94.4	40.9
Chiller Performance Results										
CHW SP (Secondary Set Point)	44		44		44		44		44	
CHWS LWT (Secondary)	44.2		44.6		45.4		47.4		42.2	
CH-1 LWT°F, KW	42.7	392.7	42.4	396.5	41.8	395.4	42.1	393.9	40.9	401.5
CH-3 LWT, KW	40.1	404	40.1	429	40.1	396	39.9	417	43.8	
CH-3 LWT, KW	-	-	-	-	-	-	-	-	43.8	
Pump Performance Results										
Total Head Ft	29.8		32.6		47.4		67.2		67.9	
SCHWP-1 %Speed / KW	-	-	-	-	80.2	25.3	91	36.8	90.3	35.8
SCHWP-2 %Speed / KW	-	-	-	-	-		91.1	36.8	90.3	35.8
SCHWP-3 %Speed / KW	79.3	24.6	84.4	29.1	80.2	25.3	91	36.8	90.3	35.8
SCHWP-4 %Speed / KW	79.3	24.6	84.4	29.1	80.2	25.3	91	36.8	90.3	35.8
SCHWP-9 %Speed / KW	49.5	-	74.9	-	83.4	-	99.2	-	100	-
Distribution Performance Results										
CHWR / Delta-T °F	55.4	11.4	55.2	11.2	54.3	10.3	54.7	10.7	52.6	10.4
No. 100% Open Valves	17		13		12		12		12	
'CW1' GPM/CHWR°F, Bldg 2	95	54.98	102	54.71	133	54.43	153	54.57	155	51
'CW3' GPM/CHWR°F, Bldg 16	311	45.65	323	53.23	379	53.14	436	52.4	427	50.07
'CW4' GPM/CHWR°F, Bldg 1	483	63.14	516	63.4	618	62.33	732	61.83	727	59.93
'CW5' GPM/CHWR°F, ACC	677	57.18	790	55.96	860	55.39	1003	55.56	969	53.68
'CW6' GPM/CHWR°F, Bedtower	1442	55.72	1561	55.54	1876	54.67	2231	55.16	2232	53.46
'CW9' GPM/CHWR°F, Laundry	169	61.18	174	61.75	187	61.97	241	63.33	187	64.88

Table 13. Chilled Water Measurement Summary

The results of the tests were then checked against the model. The pumps in the model were overridden to the recorded speeds. The control valves in the model were limited to 100% open. The results for the case of “10 PSI” are summarized in Table 14 and Table 15.

AIR HANDLING UNIT SCHEDULE					CONTROL VALVE		
AHU	LOOP	MBH	DESIGN dT °F	GPM	Cv VALUE	STATUS	ACTUAL GPM
AH-C	B	6965	9	**1548**	419	-	574
AH-D	B	6965	9	**1548**	419		573
AH-1	B	279	11	**53**	41		49
AH-1.1	B	191	14	**27**	25	74% open	27
AH-2	B	329	10	**66**	47	91% open	66
AH-3	B	160	10	**32**	14		20
AH-4	B	37	10	**7**	3		5
AH-4A	1	68	10	**14**	8		14
AH-5	1	375	19	**40**	21		35
AH-6	B	152	10	**30**	9		16
AH-7A	1	733	10	**147**	92	43% open	147
AH-8	1	180	12	**30**	30	50% open	30
AH-8A	1	109	10	**22**	13		20
AH-9	1	252	19	**27**	14		26
AH-10	1	561	12	**93**	43		65
AH-11	1	283	19	**30**	16		30
AH-12	1	699	19	**74**	41	84% open	74
AH-13	1	120	19	**13**	-	-	-
AH-14	1	124	19	**13**	-	-	-
AH-15	1	353	19	**37**	17		38
AH-16	1	412	19	**43**	-	-	-
AH-17	1	463	19	**49**	-	-	-
AH-18	1	505	19	**53**	23		51
AH-19	1	702	9	**156**	39		45
AH-21	1	213	19	**22**	-	-	-
AH-22	1	126	19	**13**	-	-	-
AH-54	B	157	10	**31**	29	20% open	31
AH-24	16	1883	10	**377**	143		294
AH-29	L	530	19	**56**	-	-	-
AH-40	L	513	10	**103**	-	-	-
AH-41	L	513	10	**103**	-	-	-
AH-42	L	573	10	**115**	-	-	-
AH-43	L	573	10	**115**	-	-	-
AH-58	2	114	10	**23**	-	-	-
AH-59	2	236	10	**47**	-	-	-
AH-60	2	128	10	**26**	-	-	-
AH-44	8	444	10	**89**	-	-	-
AH-45	8	517	10	**103**	-	-	-
AH-46	8	1312	10	**262**	-	-	-
AH-47	8	527	10	**105**	-	-	-
AH-48	8	461	10	**92**	-	-	-
AH-49	8	902	10	**180**	-	-	-
AH-50	8	537	10	**107**	-	-	-
AH-51	8	385	10	**77**	41		42
AH-12B	B	289	12	**48**	32	72% open	48
FC-BULB	1	89	9	**20**	18	62% open	20
FC-5ORIG	1	21	9	**5**	3		3
FC-PBASE	B	43	9	**10**	5		7
FC-LAUN1	L	29	9	**6**	-	-	-
FC-LAUN2	L	15	9	**3**	-	-	-
FC-LAUN3	L	15	9	**3**	-	-	-
FC-AMB1	8	54	9	**12**	8		5
FC-AMB3	8	32	9	**7**	-	-	-
FC-AMB4	8	16	9	**4**	-	-	-
FC-AMB6	8	22	9	**5**	-	-	-

Table 14. Model AHU results with 10 PSI limit (pink indicates 100% open)

AHU GROUP FLOW				CONTROL VALVE		
GROUP	LOOP	DESIGN dT °F	GPM	Cv VALUE	STATUS	ACTUAL GPM
1	L	11	**503**	*262*		425
2	8	10	**300**	*203*		276
3	8	10	**198**	*133*		137
4	8	10	**16**	*8*		8
5	8	10	**443**	*299*		262
6	1	19	**92**	*54*		76
7	1	19	**36**	*18*	87% open	36
9	1	19	**26**	*14*		25
10	2	10	**96**	*52*		92

AVERAGE CHWR TEMPS		
LOOP	GPM	dT °F
B	1445	9.4
L	425	11.0
1	704	14.8
8	733	10.0
16	296	10.0
2	92	10.0
TOTAL	3694	10.8

Table 15. Model AHU and flow results with 10 PSI limit (pink indicates 100% open valve)

The *GPM* is determined by the air-side requirements (flow, outside temperature/humidity, and return air temperatures). The *ACTUAL GPM* is what was achieved. The pink cells indicate that the control valve is 100% open. Determining this flow at 100% open requires knowledge of both the exact coil pressure drop and exact valve pressure drop. Where unknown, a Cv-value is chosen that corresponds to 5 PSI at design GPM, which is a common rule-of-thumb.

Overall, the results correspond well with the model.

- Bedtower flow is 1442 vs 1445 (actual to predicted).
- Building 8 flow is 677 vs 733.
- Building 16 flow is 311 vs 296.
- Building 2 flow is 95 vs 92.

However, some results did not and require further investigation.

- Laundry flow is 169 vs 425. Either the flow sensor is faulty or the units have been significantly modified.
- Building 1 flow is 483 vs 704. Currently, the cause of this discrepancy is unknown. Most of the units are new, and flows and pressure drops are well known. However, the area is under construction, so the cause could be due to unbalanced coils.
- Just as the actual, many of the control valves were 100% open. Some are the predicted unit, while others do not correspond. Once the Cv-values are known, however, the results will become more consistent.

The results for the case of "29.5 PSI" are summarized in Table 16 and Table 17.

AIR HANDLING UNIT SCHEDULE					CONTROL VALVE		
AHU	LOOP	MBH	DESIGN dT °F	GPM	Cv VALUE	STATUS	ACTUAL GPM
AH-C	B	9159	9	**2035**	*419*	-	958
AH-D	B	9159	9	**2035**	*419*		958
AH-1	B	292	11	**55**	*41*		50
AH-1.1	B	201	14	**28**	*25*	77% open	28
AH-2	B	417	10	**83**	*47*	56% open	83
AH-3	B	160	10	**32**	*14*	87% open	32
AH-4	B	42	10	**8**	*3*		8
AH-4A	1	90	10	**18**	*8*	62% open	18
AH-5	1	408	19	**43**	*21*	69% open	43
AH-6	B	185	10	**37**	*9*		27
AH-7A	1	964	10	**193**	*92*		174
AH-8	1	221	12	**37**	*30*	33% open	37
AH-8A	1	143	10	**29**	*13*	76% open	29
AH-9	1	275	19	**29**	*14*	55% open	29
AH-10	1	636	12	**106**	*43*	87% open	106
AH-11	1	307	19	**32**	*16*	52% open	32
AH-12	1	760	19	**80**	*41*	48% open	80
AH-13	1	131	19	**14**	-	-	-
AH-14	1	138	19	**14**	-	-	-
AH-15	1	384	19	**40**	*17*	49% open	40
AH-16	1	438	19	**46**	-	-	-
AH-17	1	504	19	**53**	-	-	-
AH-18	1	549	19	**58**	*23*	68% open	58
AH-19	1	923	9	**205**	*39*		77
AH-21	1	232	19	**24**	-	-	-
AH-22	1	137	19	**14**	-	-	-
AH-54	B	207	10	**41**	*29*	30% open	41
AH-24	16	2192	10	**438**	*143*	84% open	438
AH-29	L	590	19	**62**	-	-	-
AH-40	L	674	10	**135**	-	-	-
AH-41	L	674	10	**135**	-	-	-
AH-42	L	754	10	**151**	-	-	-
AH-43	L	754	10	**151**	-	-	-
AH-58	2	139	10	**28**	-	-	-
AH-59	2	310	10	**62**	-	-	-
AH-60	2	161	10	**32**	-	-	-
AH-44	8	499	10	**100**	-	-	-
AH-45	8	563	10	**113**	-	-	-
AH-46	8	1436	10	**287**	-	-	-
AH-47	8	574	10	**115**	-	-	-
AH-48	8	505	10	**101**	-	-	-
AH-49	8	982	10	**196**	-	-	-
AH-50	8	584	10	**117**	-	-	-
AH-51	8	484	10	**97**	*41*	75% open	97
AH-12B	B	314	12	**52**	*32*	40% open	52
FC-BULB	1	89	9	**20**	*18*	28% open	20
FC-5ORIG	1	21	9	**5**	*3*		5
FC-PBASE	B	43	9	**10**	*5*	64% open	10
FC-LAUN1	L	29	9	**6**	-	-	-
FC-LAUN2	L	15	9	**3**	-	-	-
FC-LAUN3	L	15	9	**3**	-	-	-
FC-AMB1	8	54	9	**12**	*8*	41% open	12
FC-AMB3	8	32	9	**7**	-	-	-
FC-AMB4	8	16	9	**4**	-	-	-
FC-AMB6	8	22	9	**5**	-	-	-

Table 16. Model AHU results with 29.5 PSI limit and CH-4 enabled (pink indicates 100% open)

AHU GROUP FLOW				CONTROL VALVE		
GROUP	LOOP	DESIGN dT °F	GPM	Cv VALUE	STATUS	ACTUAL GPM
1	L	11	**646**	*262*	81% open	646
2	8	10	**329**	*203*	33% open	329
3	8	10	**216**	*133*	37% open	216
4	8	10	**16**	*8*	47% open	16
5	8	10	**484**	*299*	40% open	484
6	1	19	**99**	*54*	55% open	99
7	1	19	**39**	*18*	51% open	39
9	1	19	**28**	*14*	51% open	28
10	2	10	**122**	*52*	63% open	122

AVERAGE CHWR TEMPS		
LOOP	GPM	dT °F
B	2248	9.3
L	646	11.0
1	914	14.6
8	1153	10.0
16	438	10.0
2	122	10.0
TOTAL	5522	10.6

Table 17. Model AHU and flow results with 29.5 PSI limit and CH-4 enabled (pink indicates 100% open valve)

At the higher pressure, the model predicts that fewer valves are 100% open. However, the actual results had more valves failing than the model predicts.

- In the model, none of the Building 8 coils fail. In the actual test, ACC-AHU-3 failed on all tests. The coil and Cv-values have been requested.
- In the model, AHU-24 is 84% open and satisfied. In the actual test, the coil was not meeting setpoint by 3.5°F. Again, the coil and valve data shall be updated to reflect actual.

Other than those mentioned above, where the model predicts failure, failure is indeed occurring.

Update: Several items were identified AFTER the 7/13/2012 Experiment that CORRECTED the model.

1. ***Valve to old 8" main was found 90% closed. This explains why the model poorly predicted Bldg 1.***

2. ***Many control valve Cv-values and balancing valve settings were investigated and identified.***

3. ***Initially, the thought was that the Laundry flow sensor, 'CW9' was faulty. Instead, the laundry units were identified as being oversized and running at low setting. The 'CW9' sensor appears to be correct.***

Appendix H. Pipe Velocity Report (Phase 11)